Tricks of the trade for analysts in the energy biz

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Preliminaries: Genesis of this course

- Names and introductions.
- Tim wanted a review of “energy math” and of the structure of the U.S. energy system.
- *Turning Numbers into Knowledge* deals with many key tricks of the trade.
- Purpose is to help you “get it right” in a timely way.

Introduction: Philosophy

- It takes work to absorb tools, tricks, and data--there's no substitute for organization, discipline, and focus.
- Know what you know, and what you don't know.
- Get it 70-90% right while noting uncertainties and data holes (much better than getting 99% and being late).

Put facts at your fingertips: Key references and data sources

- Get organized--be systematic in your use of information.
- Put widely used sources within easy reach (build a personal library and data sheet).
- Make friends with a reference librarian.
- Statistical Abstract of the U.S., almanacs, web sources (see Ch. 9 of book)

Put facts at your fingertips: Documentation

- Always date your work, even your roughest handwritten notes. Put date / time stamp in footer of spreadsheets and manuscripts.
- Stamp “Draft” and “Confidential”, as appropriate.
- Carefully document code and assumptions in spreadsheets.

Understanding Data: Pitfalls in data acquisition and handling

- Holdren's four golden rules
  - Avoid data that are mislabeled, ambiguous, badly documented, or otherwise of unclear pedigree
  - Discard unreliable data that are invented, cooked, or incompetently created
  - Beware of illusory precision
  - Avoid spurious comparability

Understanding data: Techniques for success

- Be skeptical of statistics, even official ones
  - Miscellaneous electricity story
  - Self generation data in a restructured market
  - CA electricity use (CEC estimate not equal to EIA estimate)
- Check for internal consistency
- Identify numbers that are too small or large.
- Read the footnotes.

Understanding data: Techniques for success (p.2)

- Rounding errors (note different conventions)
  - 91.4 = 91 when rounded.   2.4 = 2 when rounded. The sum of the rounded numbers is 93, but the sum of 91.4 and 2.4 rounds to 94.
- Type data into the spreadsheet yourself.
- Check that totals = the sum of the subtotals.
- Check that the input data are correct and current (e.g., 1990s model using 1970s data)

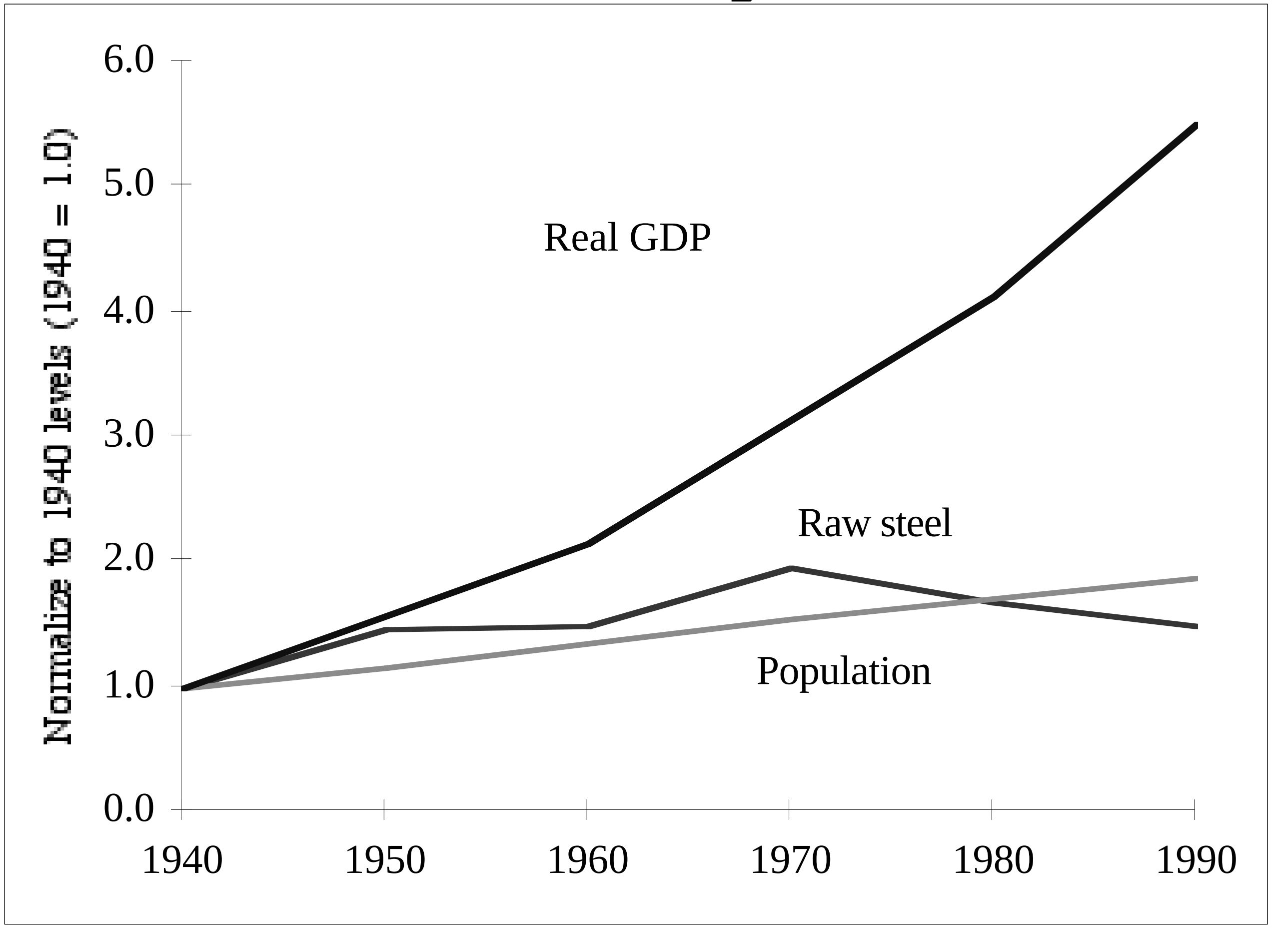
Understanding data: Techniques for success (p. 3)

- Check relationships between numbers that should be related in a predictable way.
- Compare the numbers to something else with which you are familiar, as a "sanity check".
- Check that you can trace the calculation through from data to final results.

Understanding data: Consistent comparisons

- Always note the year for dollars.
- Correct dollars for inflation (nominal vs. real)--see data sheet
  - Use GDP deflator, CPI, or specialized indices
  - Nominal interest rate = Real interest rate + inflation
- Normalize numbers to make comparisons easier (per GDP, per capita, per physical unit [like kWh], or to a base year).

Understanding data: Normalizing to a base year



Back of the envelope calculations: Introduction

- You can figure out almost anything in an approximate way. You may not believe it, but it's true!
- The most successful business people and researchers do these calculations instinctively, but it is a skill that can be learned.

Back of the envelope calculations: Some key info

- deca = 10, k = kilo = Thousand = 1,000 = 10^3, M = mega = Million = 1,000,000 = 10^6, G = giga = Billion (except if you're British) = 1,000,000,000 = 10^9, T = tera = Trillion = 1,000,000,000,000 = 10^{12}, P = peta = Quadrillion = 1,000,000,000,000,000 = 10^{15}, E = exa = Quintillion = 1,000,000,000,000,000,000 = 10^{18}
- Exponential notation: 10^2 = 100, 10^3 = 1,000. The exponent equals the number of zeros. This notation is also sometimes written 10e2. So, kilo = 10^3, mega = 10^6, etc. Note also that 10^0 = 1. To multiply, add exponents. To divide, subtract exponents.

Back of the envelope calculations: General approach

- First make a model, balancing accuracy against the time needed to create the calculation
  - Back of the envelope, spreadsheet, or code
- A simple model
  - Gas used per week (gallons) = $\frac{\text{miles driven}}{\text{week}} \times \frac{\text{gallon}}{\text{miles}}$
  - If a car gets 20 mpg in normal use, for a 1000 mile trip, the simple estimate is that the car will use 50 gallons.

BOE calculations: A more complex model

- If a 1000 mile trip doesn't have same highway/city split as normal use, must rely on the 2d model
  - Gas/week (gals) = $\frac{\text{City miles}}{\text{week}} \times \frac{\text{gallon}}{\text{City miles}} + \frac{\text{Highway miles}}{\text{week}} \times \frac{\text{gallon}}{\text{Highway miles}}$
  - assuming 15 mpg city, 25 mpg highway, 95:5 split between highway and city driving, yields 41.3 gallons
- Assumptions about how many miles driven are *buried* in the first model. There are *always* buried assumptions

BOE calculations: some advice

- Once you’ve made a model, plug in the numbers you know, and make assumptions for those you don’t know.
- Don’t get hung up on a particular number! Set up the calculation and get data later.
- Don’t be afraid to approximate to speed things up (e.g., to divide 4000 by 35, divide 3500 by 35 instead to get 100).

BOE calculations: More tips

- Bound the problem
  - Plug in high and low estimates for key parameters
  - Combine all high estimates in one scenario, and all low estimates in another
  - Test sensitivity of each variable to arbitrary changes in inputs
- Create a data sheet, and memorize key conversion factors (handout)
- Understand commonly used units (Quads, TWh, joules, Mbtus, MMBtus, kW vs kWh, tons)

BOE calculations: Unit analysis

- You can always multiply some number by 1 without changing its value.
- Example: Calculate the average load over 1 year (kW) for an electricity end-use that consumes 10,000 kWh per year

$$\frac{10{,}000\ \text{kWh}}{\text{year}} \times \frac{1\ \text{year}}{8760\ \text{hours}} = 1.14\ \text{kW}$$

In that equation, the hours and the years cancel, yielding kW.

BOE calculations: Unit analysis (p.2)

- What is a Watt, and why does kWh have hours in it?
  - 1 Watt = 1 Joule/second
  - A watt is a rate of flow, like gallons of water per hour. A watt-hour is the amount of energy if a 1 Watt power drain continues for 1 hour (it's like the water that collects in the tub, in gallons).
  - So if a 1 gallon per minute flow rate continues for 1 hour, there will be 60 gallons of water in the tub after 1 hour. If a 1000 W load continues for 1 hour, then 1000 Wh (1 kWh) will be used (i.e., will be "in the tub").

BOE calculations: Unit analysis (p.3) and concluding remarks

- Let's show that 1 kW = 1000 J/s:

$$\frac{1000J}{1s} \text{ x } \frac{Btu}{1055J} \text{ x } \frac{kWh}{3412\ Btu} \text{ x } \frac{3600s}{hr} = 1 \text{ kW}$$

- Let's convert 1 kWh to Joules to prove kWh is an energy unit:

$$kWh \text{ x } \frac{1000W}{1kW} \text{ x } \frac{1J/s}{1W} \text{ x } \frac{3600s}{\text{hr}} \text{ x } \frac{MJ}{10^6\ \text{J}} = 3.6 \text{ MJ}$$

- You can estimate almost anything!

Back of the envelope calculations: an exercise

- Group exercise # 1: Figure out how much electricity (kWh) was used for each home in the U.S. in 1999, using numbers you know, then calculate the total used by all U.S.households (in billion kWh)

Back of the envelope calculations: another exercise

- Group exercise #2: How much gasoline is used in the U.S. for all light duty vehicles (passenger cars, SUVs and light trucks) in 1 year? Give the answer in gallons, barrels, and quadrillion Btus per year.

Summary of the U.S. energy system: Introduction

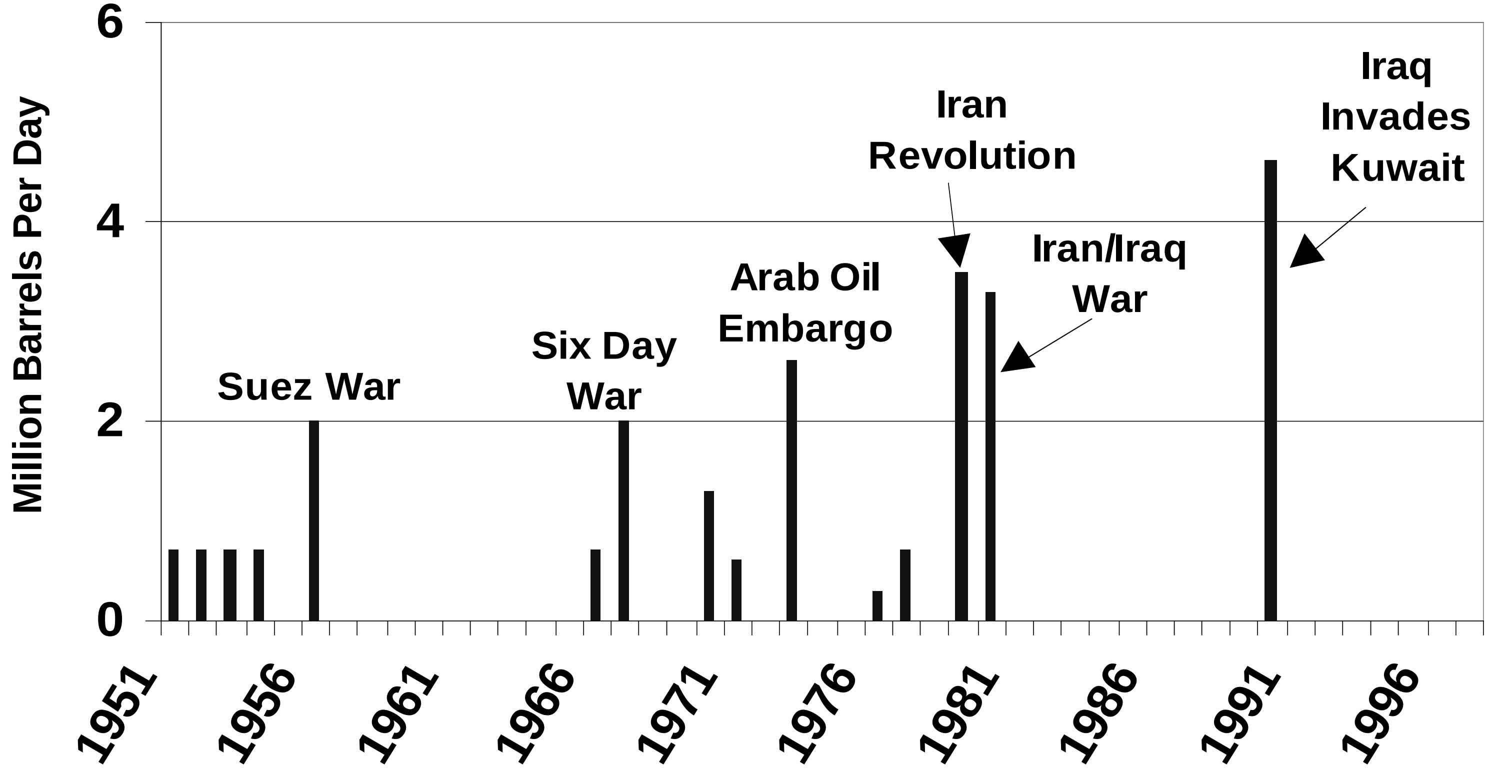
- Everyone in this industry needs to have a basic understanding the production and use of energy in the U.S.
- U.S. is the world's largest energy user, and one of the largest energy producers.
- The U.S. is also one of the largest importers of energy.

Summary of the U.S. energy system: Major events

- 1973--Arab Oil Embargo
- 1979-80--Iranian revolution, CAFE stds
- 1986--Oil price decline
- 1992--Energy Policy Act
- 1987-2001--Efficiency standards, energy Star programs.
- 2000-2001--Oil & gas price hikes, electricity crisis in CA and the West.

Major oil supply disruptions

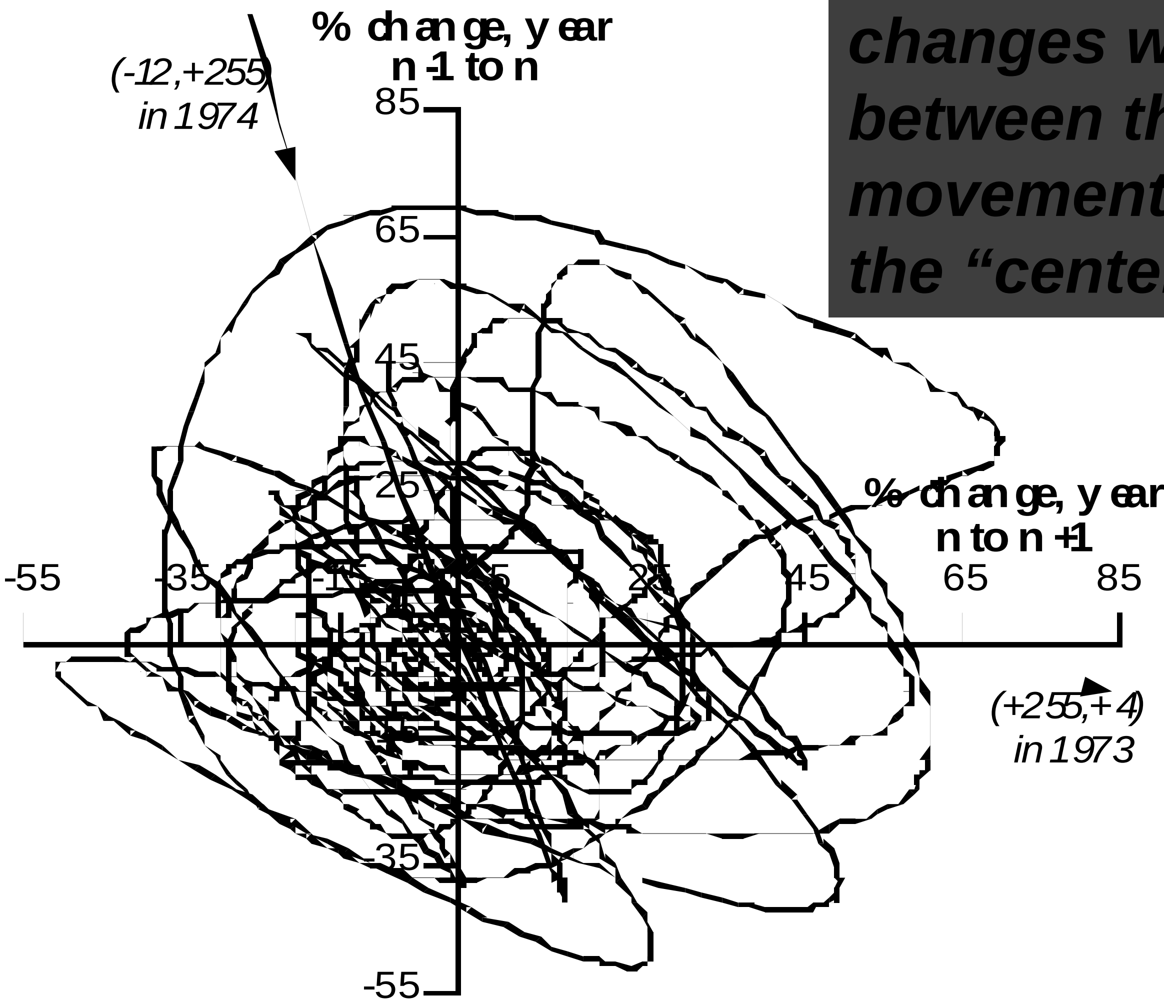
Of course, these would be best viewed normalized as a % of total world consumption.



Summary of the U.S. energy system: Lessons from history

- Forecasting is tough, but scenarios can help (Royal Dutch Shell in 1970s)
- Energy demand and GDP need not grow in lock step
- Demand-side technologies and programs can save energy at a cost that is typically half of the cost of supplying that energy.

The Brownian Random Walk of World Real Oil Price, 1881–1993



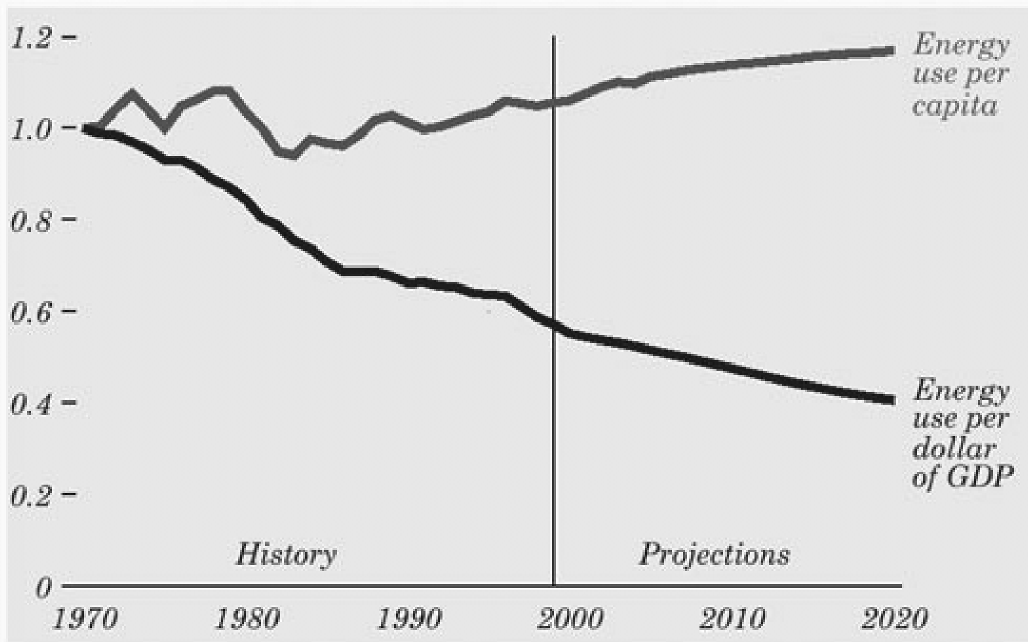
Graph used courtesy of Amory B. Lovins, RMI

Year-to-year percentage price changes with a one-year lag between the axes. If the price movements showed a trend, the "center of gravity" would favor a particular quadrant. All that happened after 1973 is that volatility tripled; changes stayed perfectly random, just as for any other commodity.

Graph devised by H.R. Holt, USDOE; presented by Rocky Mountain Institute, www.rmi.org © RMI 2001

Energy use per capita and per GDP

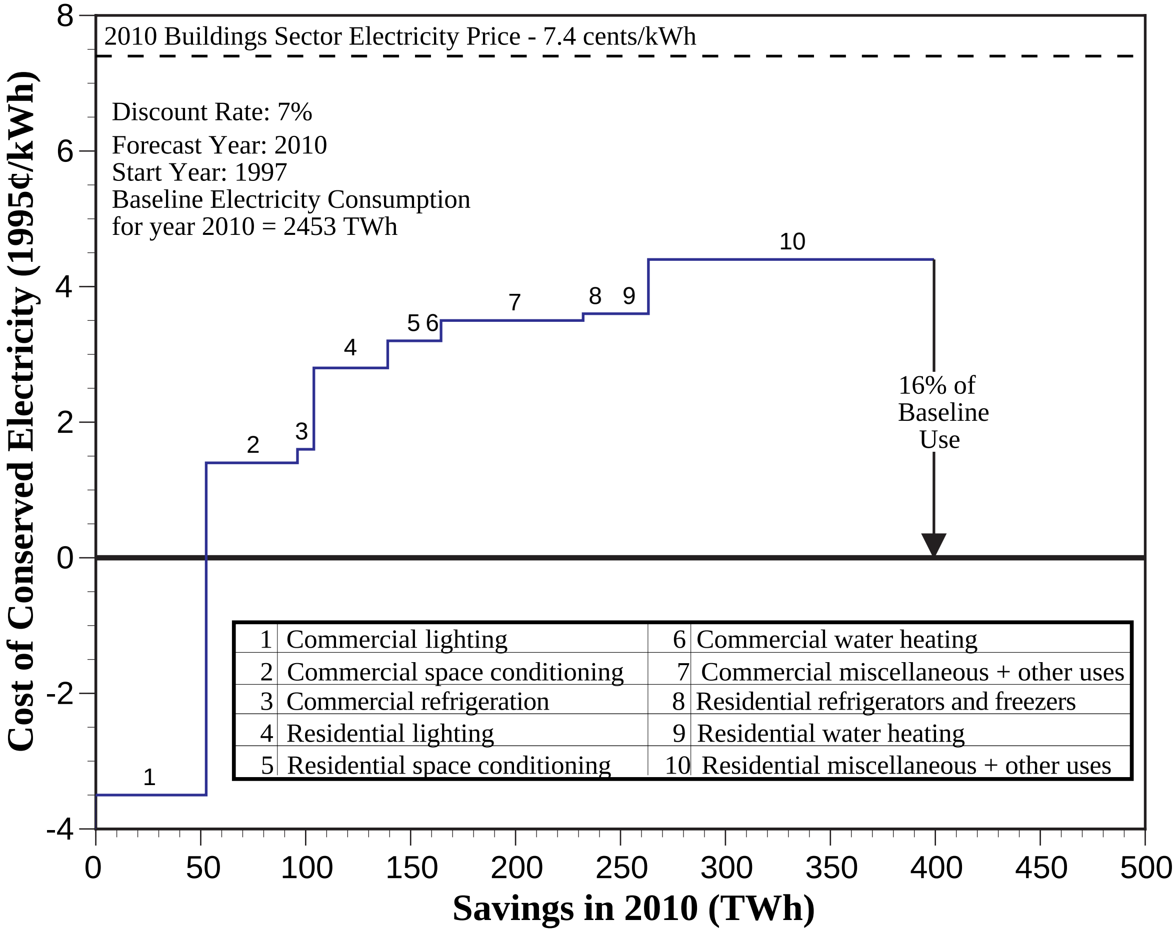
Figure 3. Energy use per capita and per dollar of gross domestic product, 1970-2020 (index, 1970 = 1)



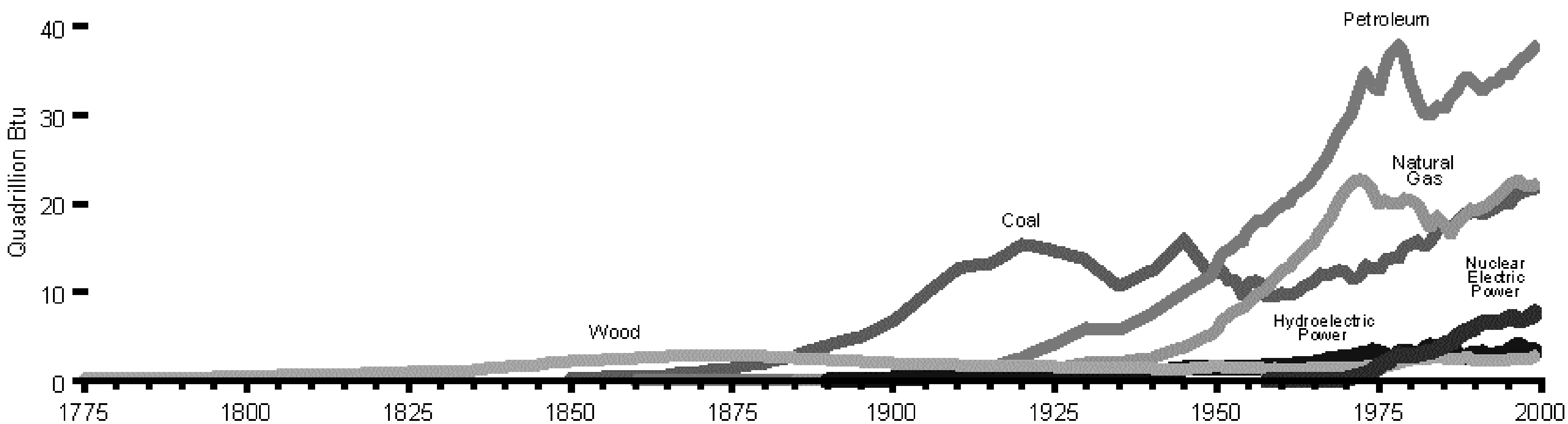
History: Energy Information Administration, *Annual Energy Review 1999*, DOE/EIA-0384(99) (Washington, DC, July 2000). **Projections:** Table A20.

Efficiency is cheaper than supply

Potential Electricity Savings from High-Efficiency Case in 2010

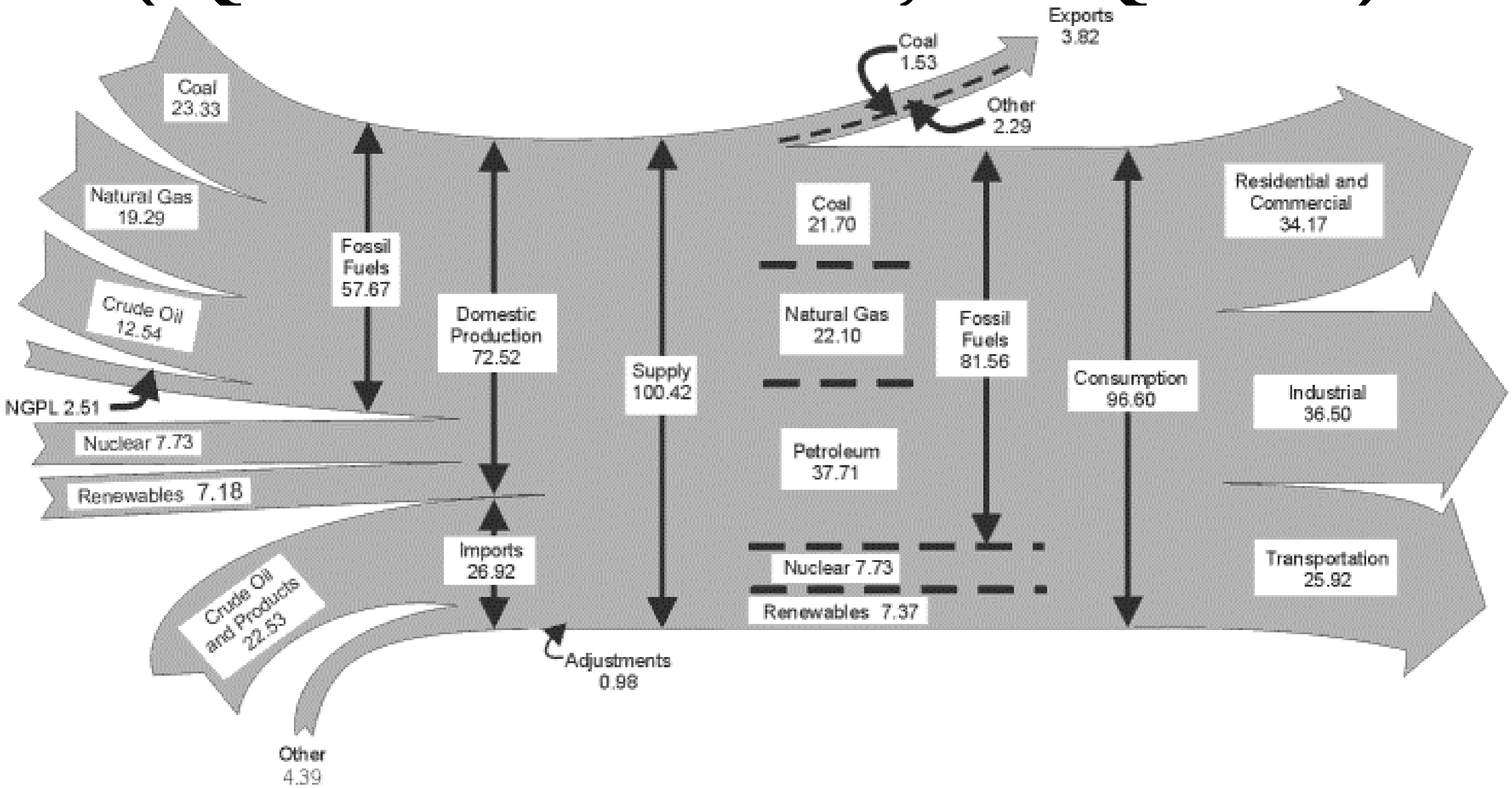


Historical U.S. energy use by fuel



Source: U.S. Energy Information Administration, U.S. DOE, *Annual Energy Review 1999*.

Energy flows in the U.S. in 1999 (Quadrillion Btus, or Quads)



Source: U.S. Energy Information Administration, U.S. DOE, *Annual Energy Review 1999*.

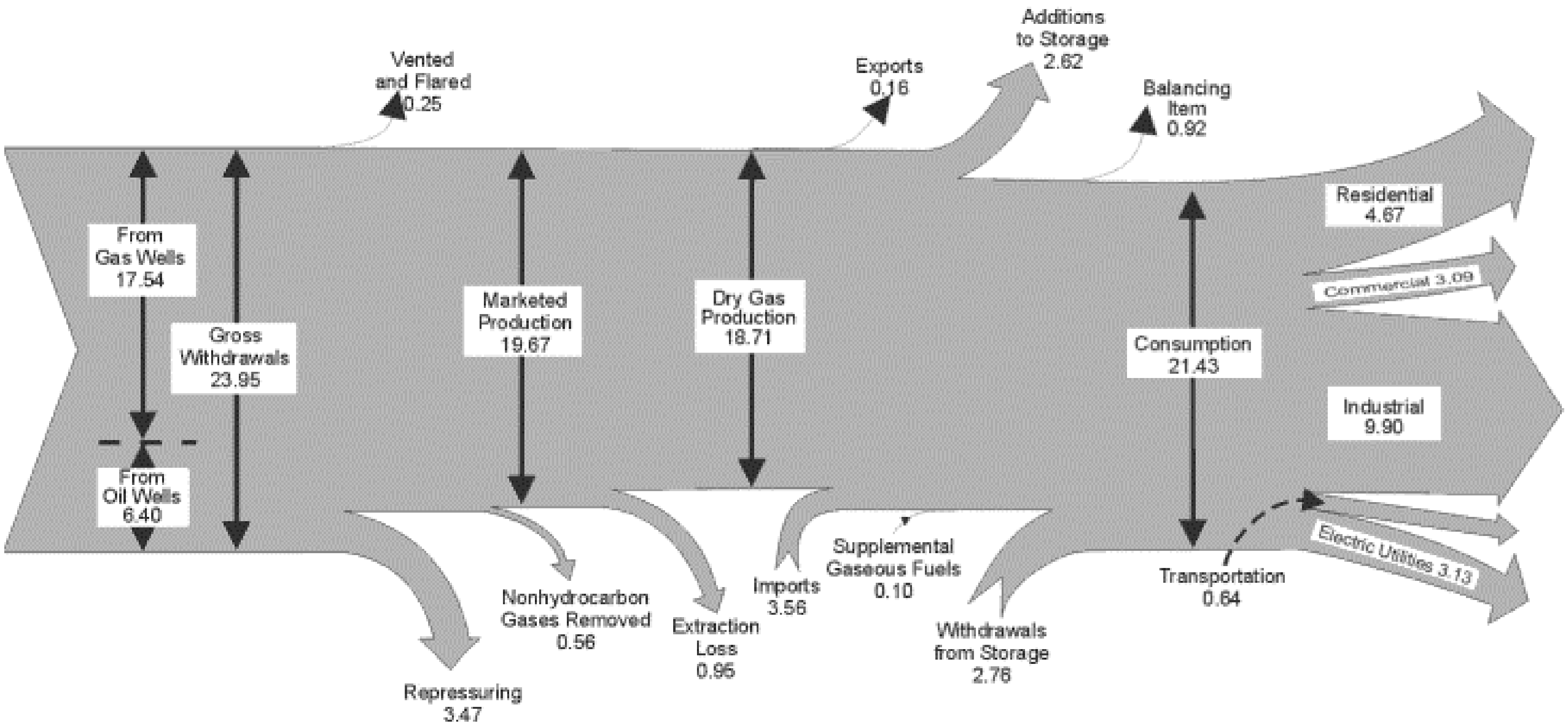
Summary of the U.S. energy system: A subtlety about electricity

- When converting electricity use from kWh to Btus, for comparison to other energy forms, you can use two different methods:
  - Site energy (measured at the customer’s meter using a conversion factor of 3412 Btus/kWh)
  - Source energy (including the generation, transmission, and distribution losses), resulting in a conversion factor that is typically 10,500 Btus/kWh (though this varies by power plant).

Summary of the U.S. energy system: A subtlety about fuels

- There are two ways to measure heat content of fuels: Lower heating value (LHV) and higher heating value (HHV)
  - LHV eliminates from the heat content the heat needed to evaporate moisture in the fuel, while HHV includes that heat content.
  - Efficiencies measured using LHV are 5-10% higher for fuel fired power plants than using HHV
  - Make sure both efficiency and prices are consistent.
  - US uses HHV, Europe uses LHV, typically.

Energy flows in the U.S. natural gas sector in 1999 (Quads)

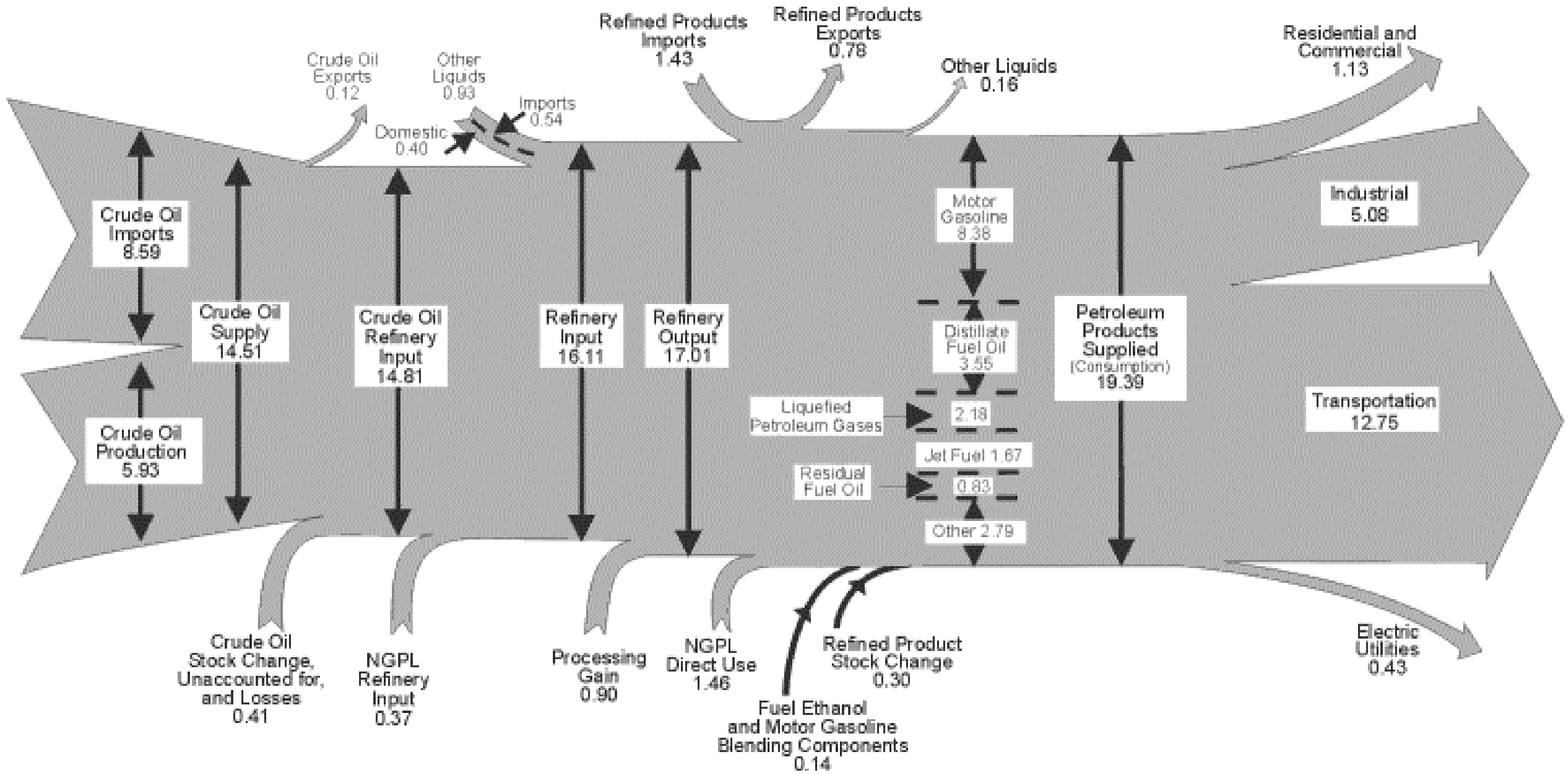


Source: U.S. Energy Information Administration, U.S. DOE, *Annual Energy Review 1999*.

Summary of the U.S. energy system: An exercise

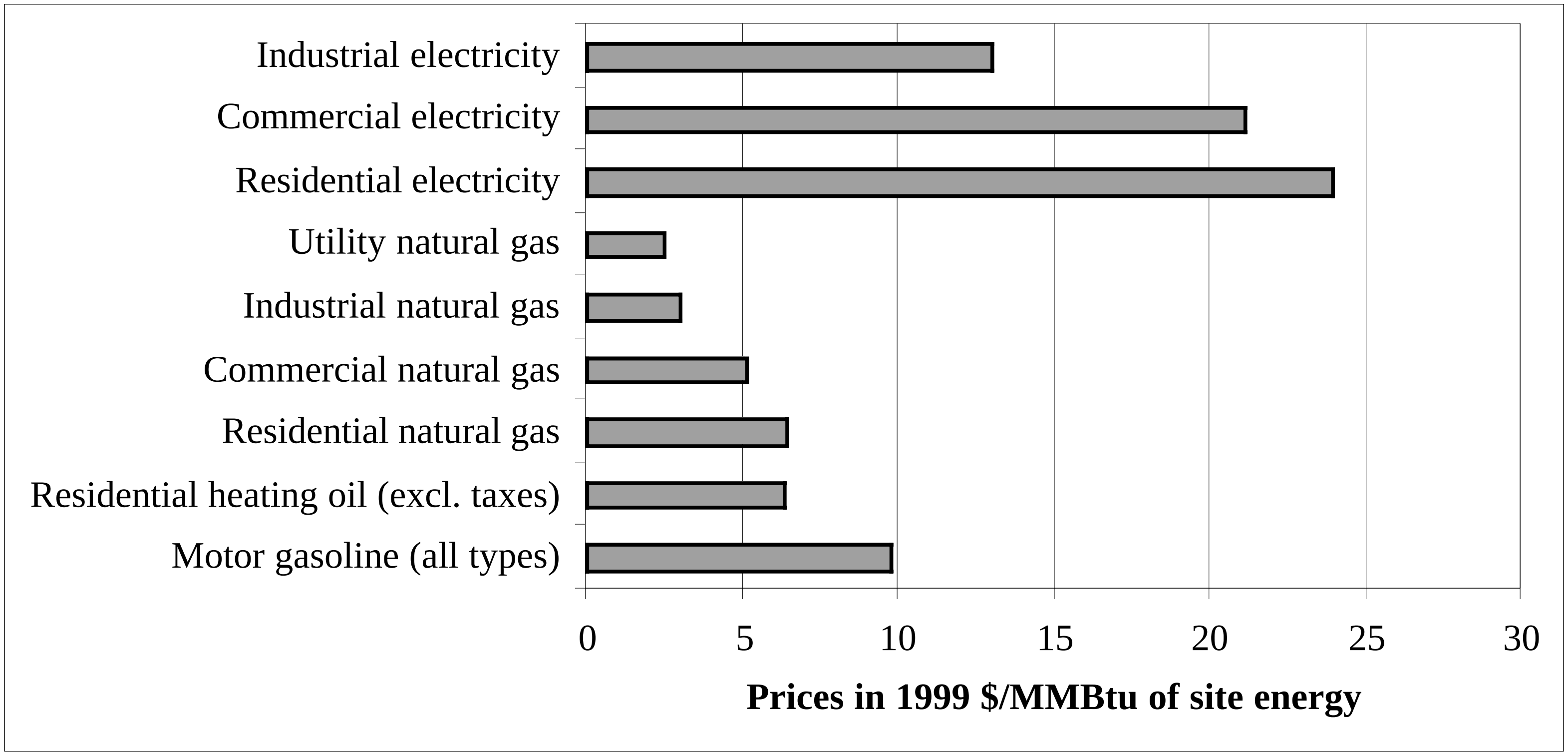
- Group exercise #3: A typical U.S. home that is heated by natural gas uses about 100 MMBtu (million Btu)/year. How much gas is that at standard temperature and pressure? How does that volume compare to that of a typical house?

Energy flows in the U.S. petroleum sector in 1999 (Quads)

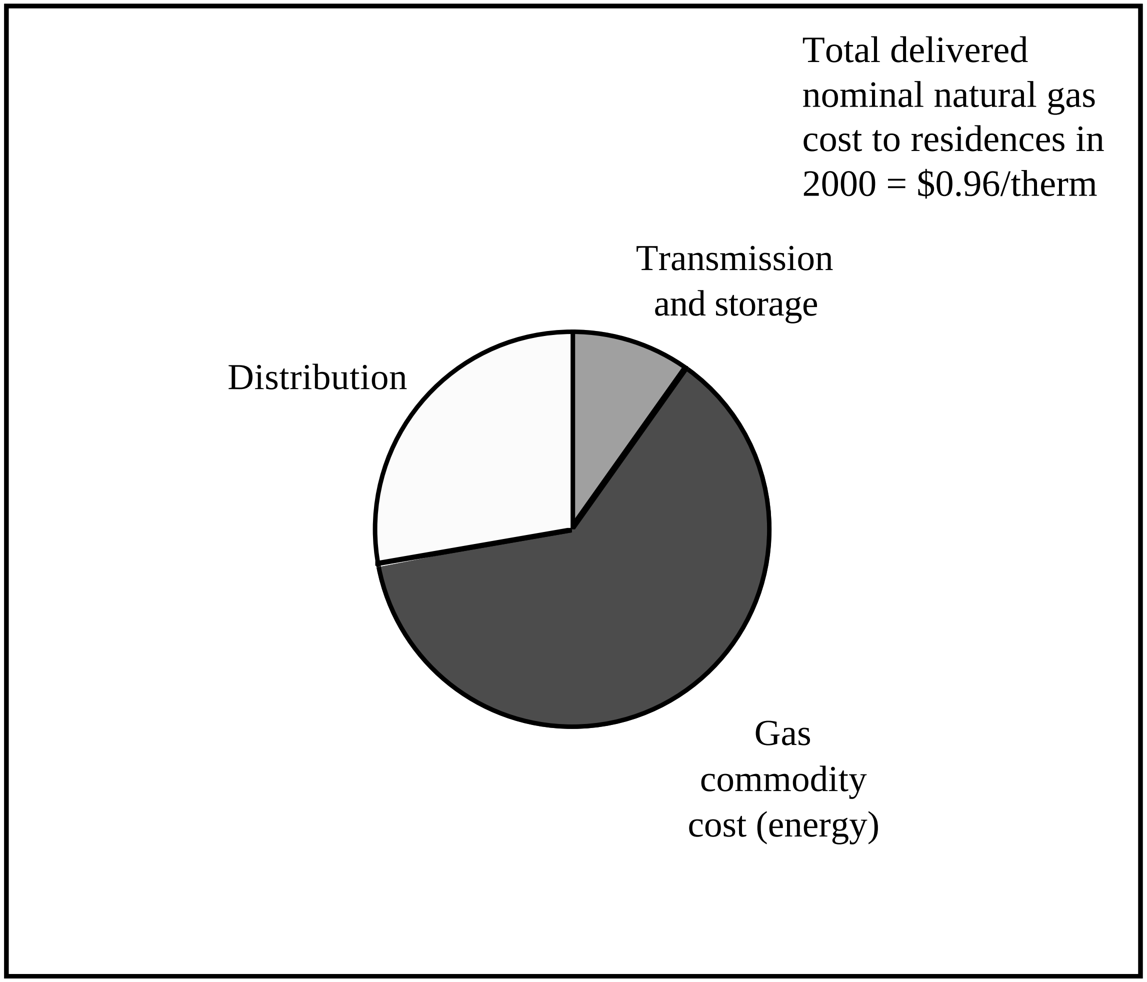


Source: U.S. Energy Information Administration, U.S. DOE, *Annual Energy Review 1999*.

Summary of the U.S. energy system: Prices



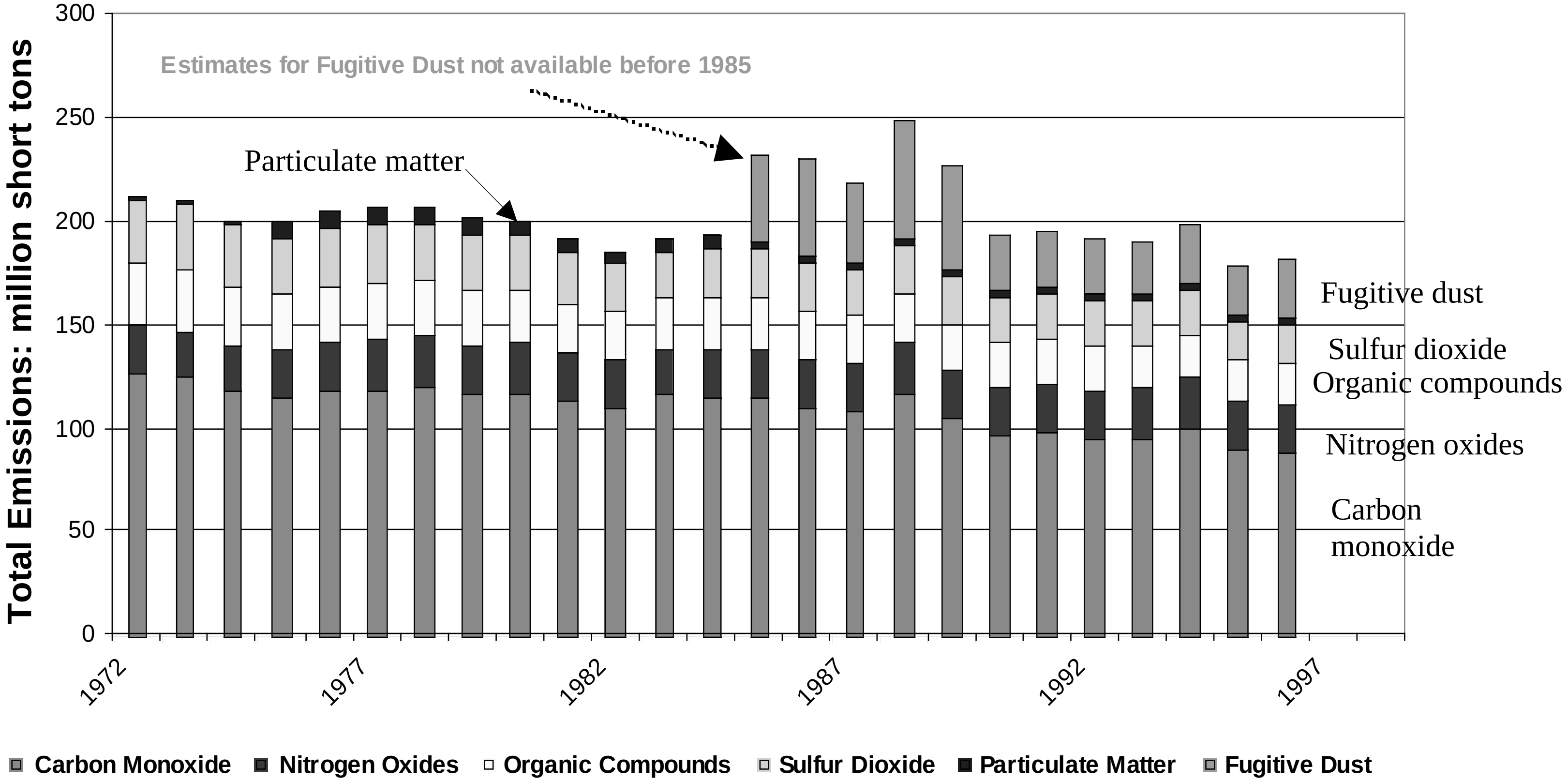
Summary of the U.S. energy system: Res. natural gas costs



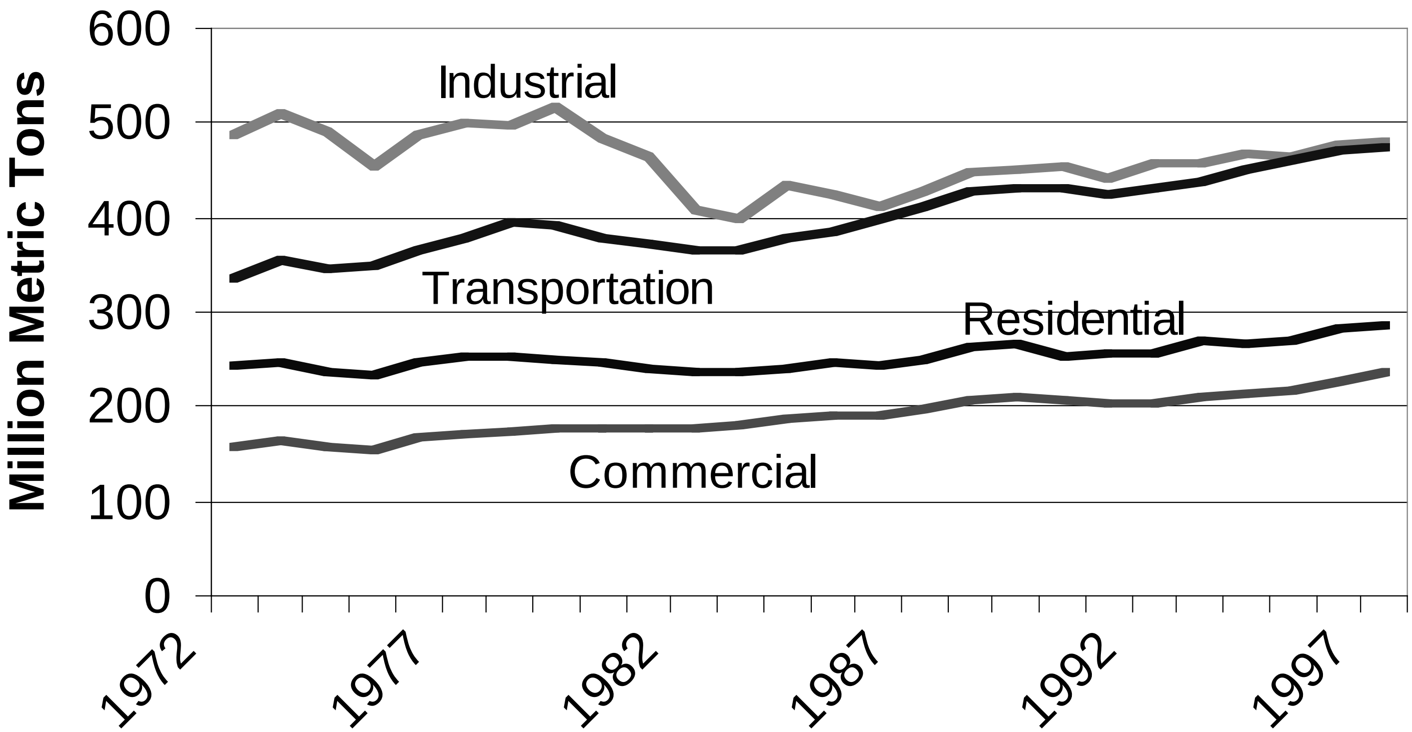
Summary of the U.S. energy system: U.S. criteria air pollutants

Source: U.S. Energy Information Administration.

Note: Real GDP roughly doubled 1972-1997, and population increased almost 30%.



Summary of the U.S. energy system: U.S. carbon emissions



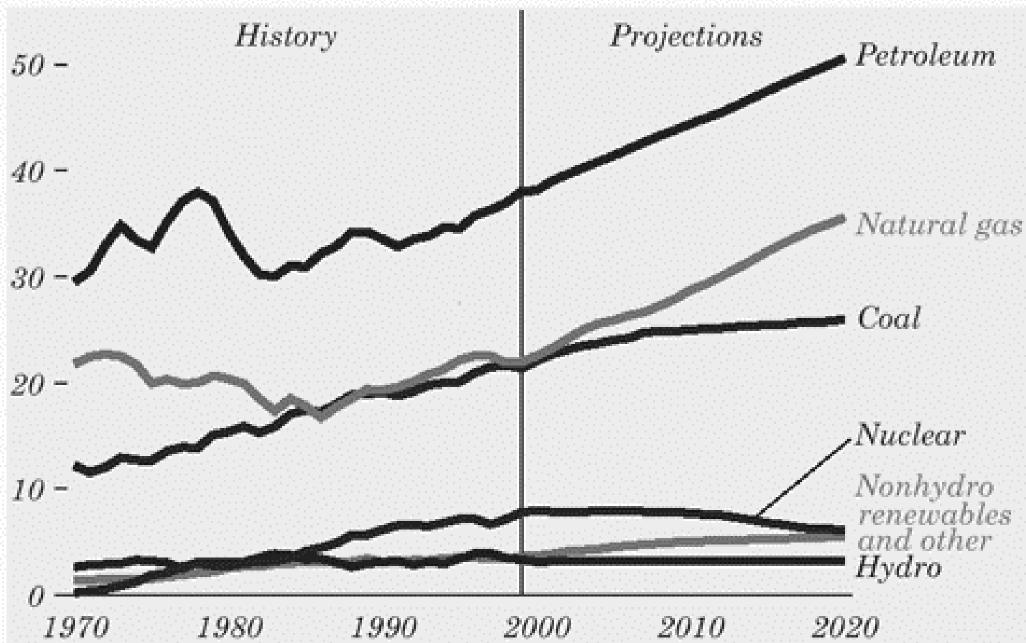
Source: U.S. Energy Information Administration.

Summary of the U.S. energy system: Forecasts

- The official source of U.S. energy forecasts is the Energy Information Administration, which is part of the U.S. Department of Energy (http://www.eia.doe.gov)
- Consult the EIA web site for their truly outstanding and colossal collection of publicly available data.

Summary of the U.S. energy system: Consumption forecasts

Figure 2. Energy consumption by fuel, 1970-2020 (quadrillion Btu)

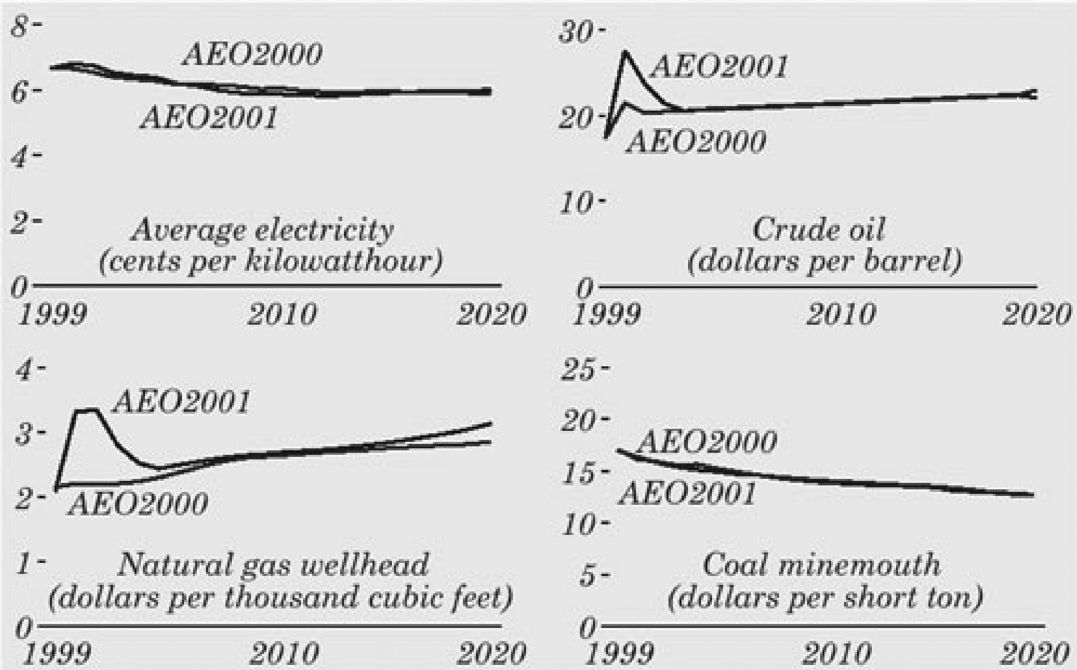


History: Energy Information Administration, *Annual Energy Review 1999*, DOE/EIA-0384(99) (Washington, DC, July 2000). **Projections:** Tables A1 and A18.

Note: Hydro is relatively small on the National scale, but is very important in the Northwest.

Summary of the U.S. energy system: Price forecasts

Figure 1. Fuel price projections, 1999-2020: AEO2000 and AEO2001 compared (1999 dollars)



Projections: Energy Information Administration, *Annual Energy Outlook 2000*, DOE/EIA-0383(2000) (Washington, DC, December 1999). ***AEO2001* projections:** Table A1.

Summary of the U.S. electricity system: Introduction

- U.S. is the world's largest electricity producer and user
- The U.S. electricity system is still one of the most reliable and cost effective in the world (CA problems notwithstanding).
- Power systems vary greatly by region.

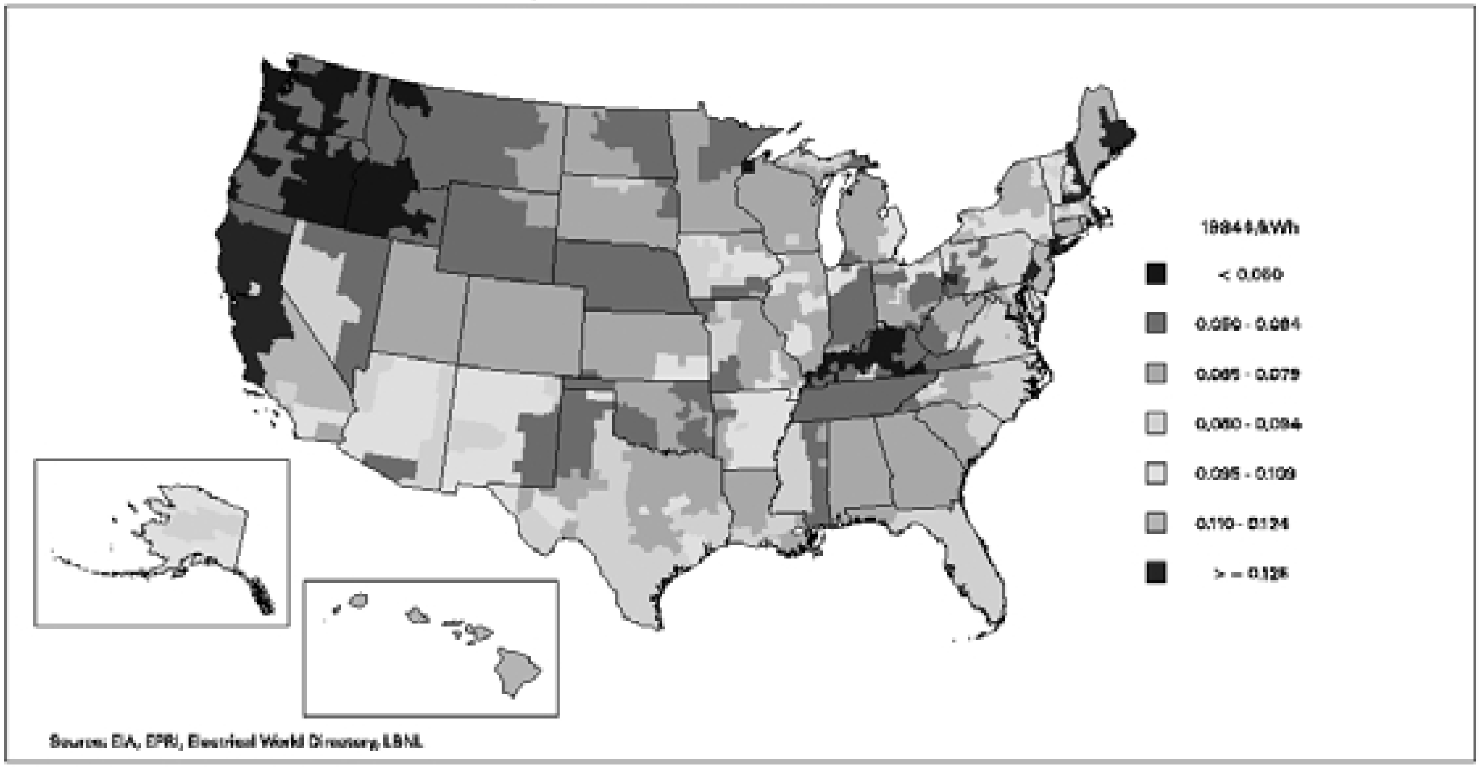
Summary of the U.S. electricity system: Major events

- Early 1900s--competitive market with multiple providers (duplication led to appreciation of natural monopoly status and the regulatory compact--obligation to serve, geographic monopoly, regulation of rates).
- Economies of scale in generation reduced costs until about 1970, then costs went up.
- 1978 PUR PA, implemented early 1980s (SO 4 in CA) --Deregulation of generation.

Summary of the U.S. electricity system: Major events (continued)

- 1987 to mid-1990s, Heyday of utility DSM
- Early to mid-1990s, realization that generation wasn't a natural monopoly any more (T&D still is, of course)
- In 1992 EPACT deregulated transmission (also FERC order 888 opened trans. up)
- Retail restructuring in mid to late-1990s, sometimes successful, sometimes not
- 2000-2001+, CA power crisis

High Electricity Prices Were a Strong Driver for Retail Restructuring - 1993



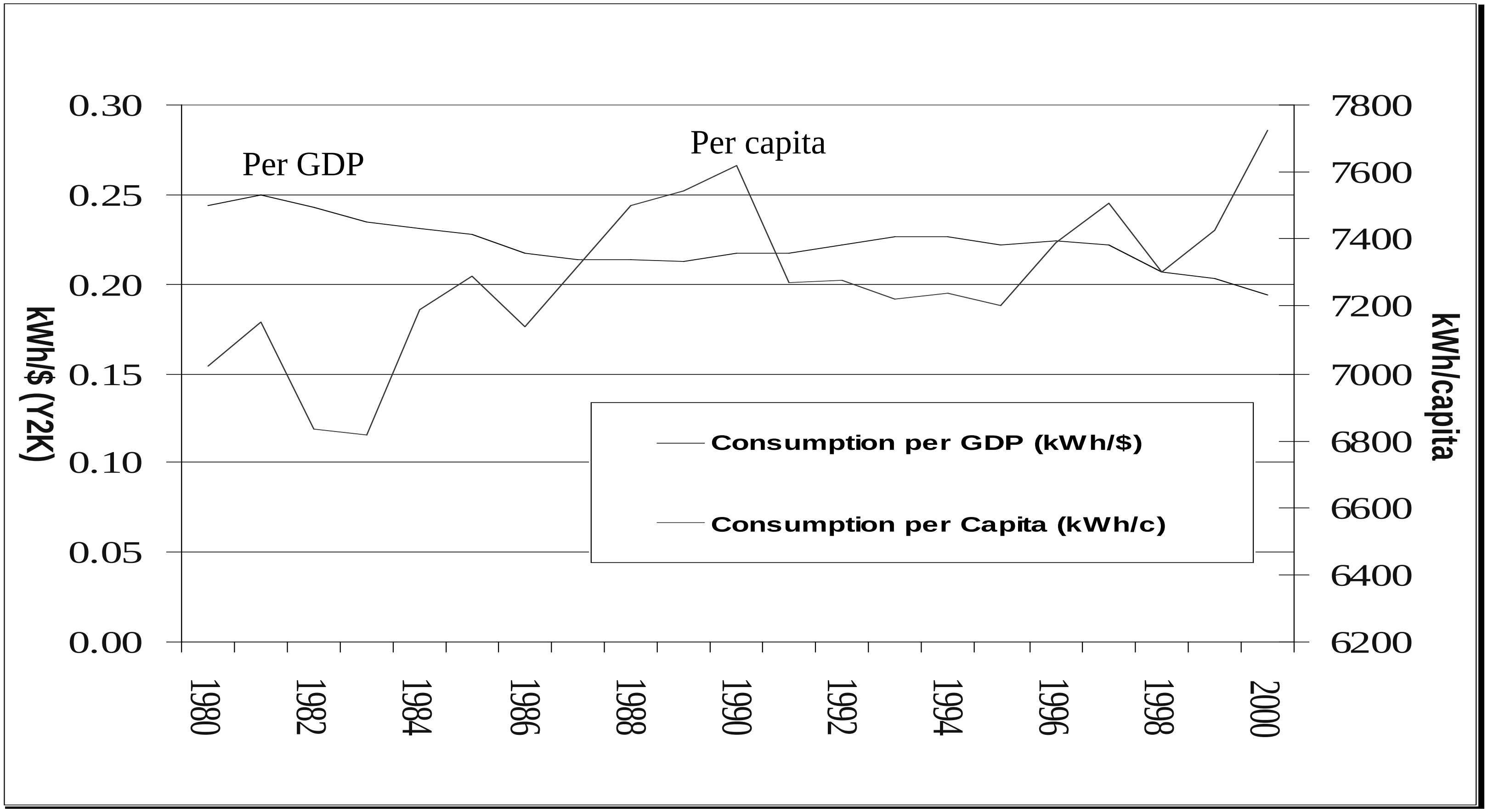
County boundaries were used as building blocks to approximate electric utility boundaries. This work was based on data from the EPRI and the Electrical World Directory. Areas that were not assigned to a utility are assigned the state average utility price. Price data for investor owned utilities is from the Energy Information Administration, and all other utility price data is from the Electrical World Directory.

elec94.aml, 01/16/97

Summary of the U.S. electricity system: Lessons from history

- Forecasting is tough, but some techniques (e.g., end-use analysis) are better than others (Huss at Northeast utilities analyzed this)
- Electricity demand and GDP need not grow in lock step, though the connection is stronger than for primary energy and GDP.
- Demand-side technologies and programs can save electricity at a cost that is typically half of the cost of supplying that energy.

Electricity Consumption Per CA GDP and Per Capita



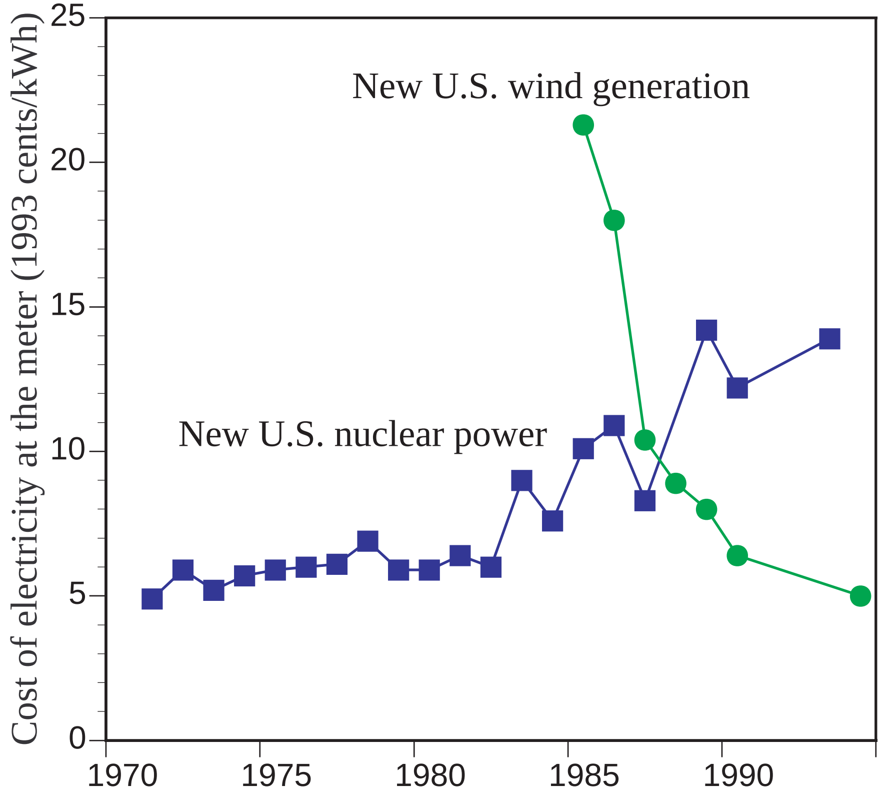
source: California Energy Commission

Side exercise: What is misleading about this graph?

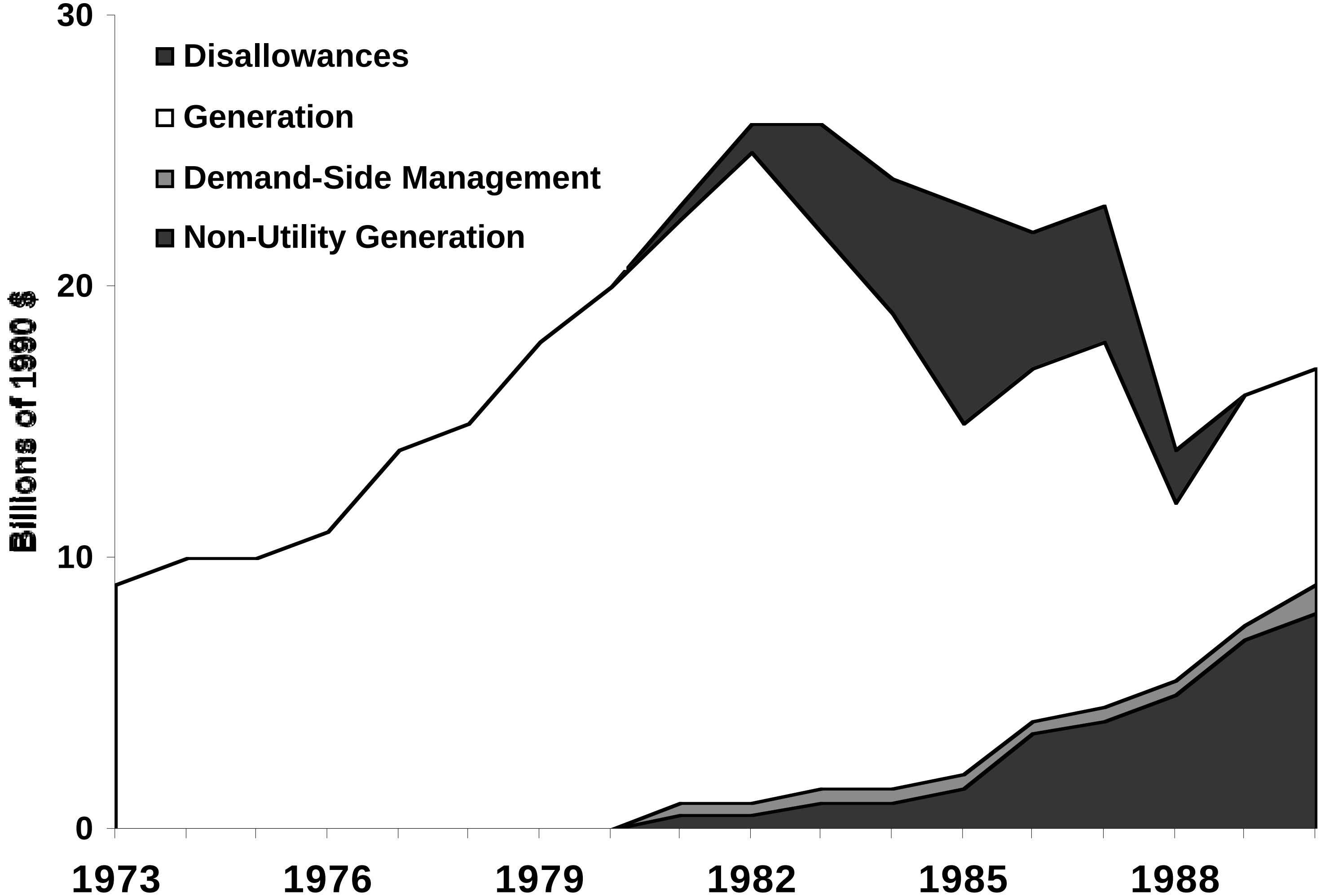
Summary of U.S. electricity system: History lessons (cont.)

- Mass-produced technologies can achieve economies of scale more quickly than can site-built technologies
- Non-utility generation can make major contributions to installed capacity

Cost of mass produced vs. site built generation technologies



Investor-Owned Utility Investment in Generation Declined in the 1980's



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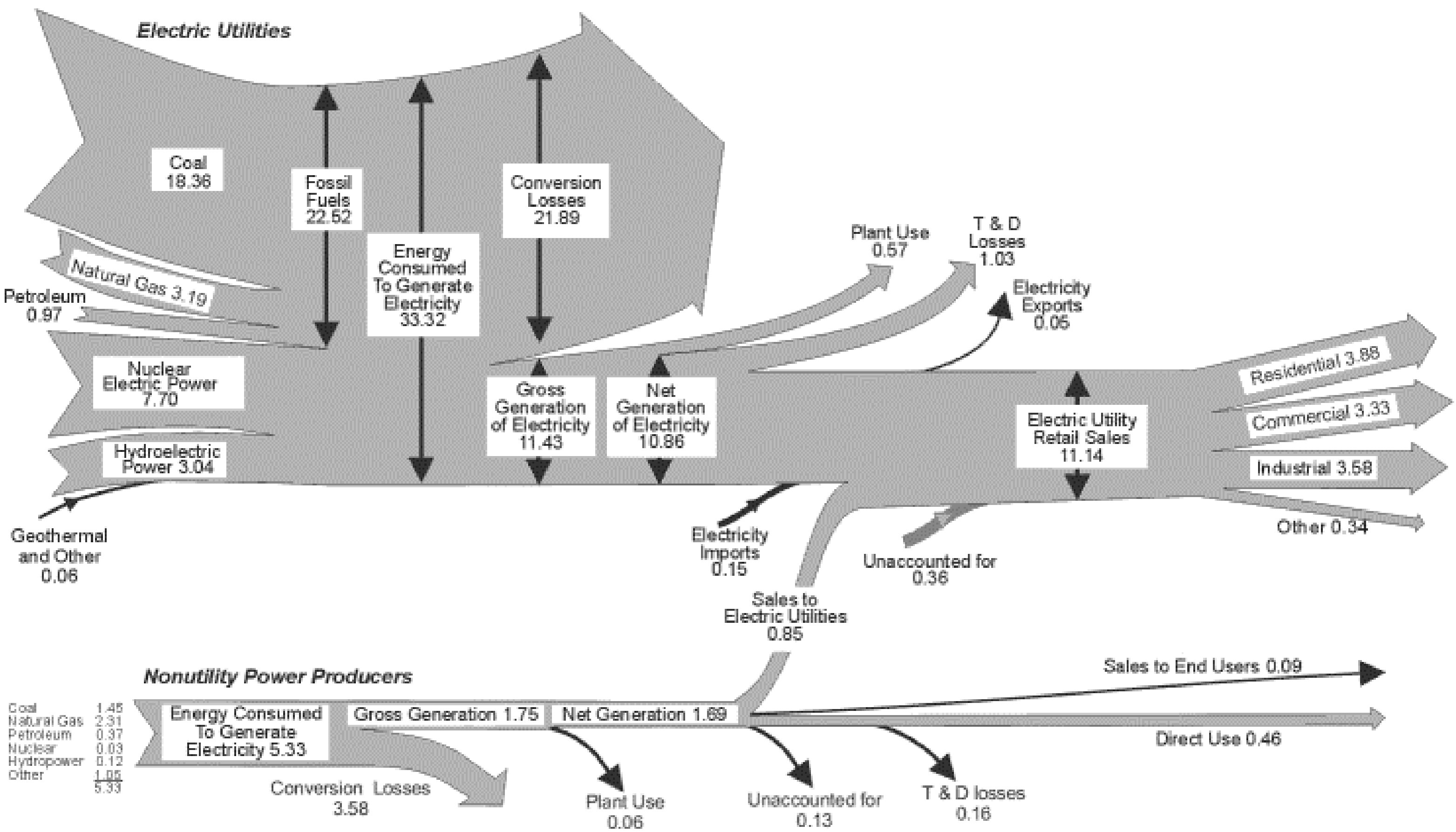
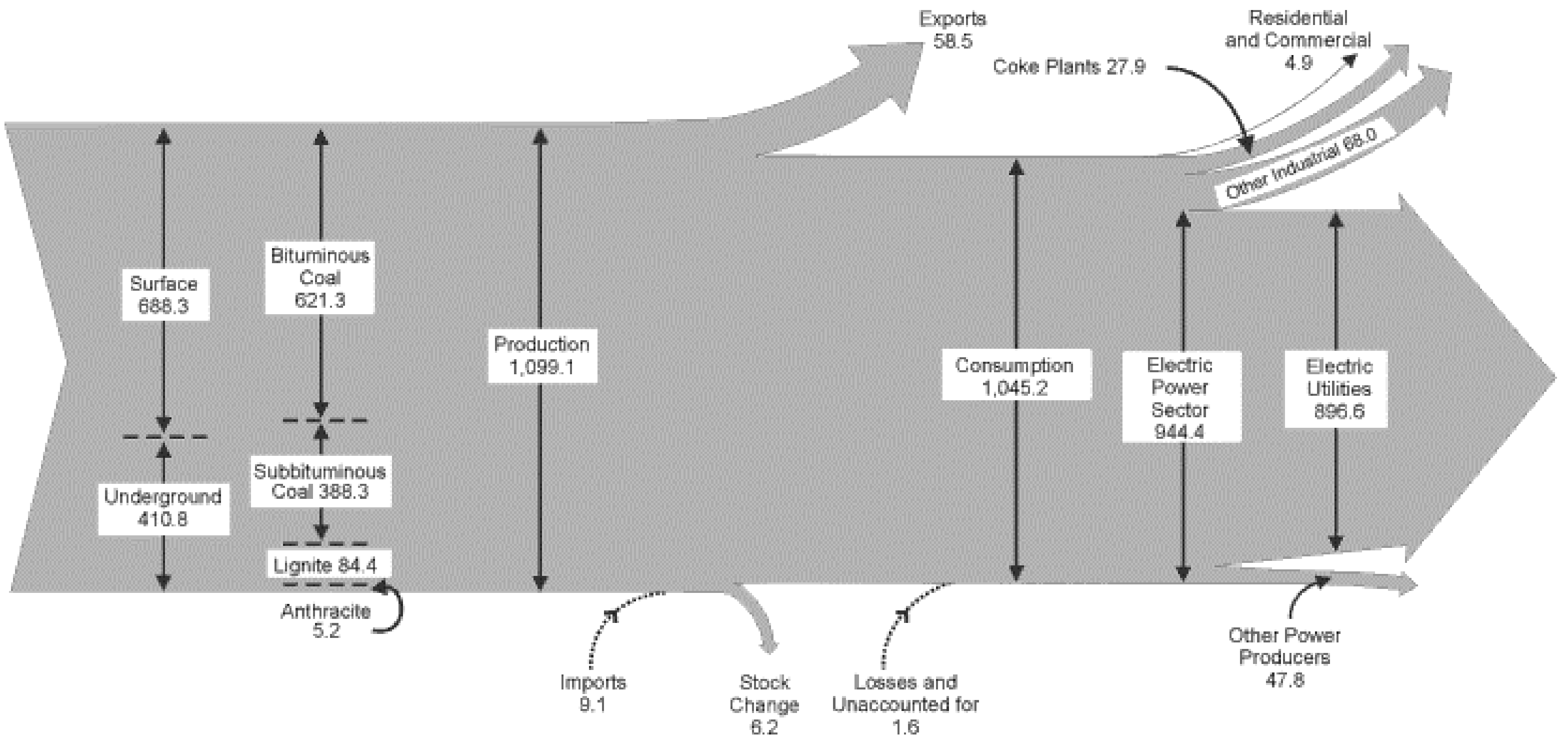
Energy flows in the U.S. electricity sector in 1999 (Quads)



Source: U.S. Energy Information Administration, U.S. DOE, *Annual Energy Review 1999*.

Energy flows in the U.S. coal sector in 1999 (Quads)

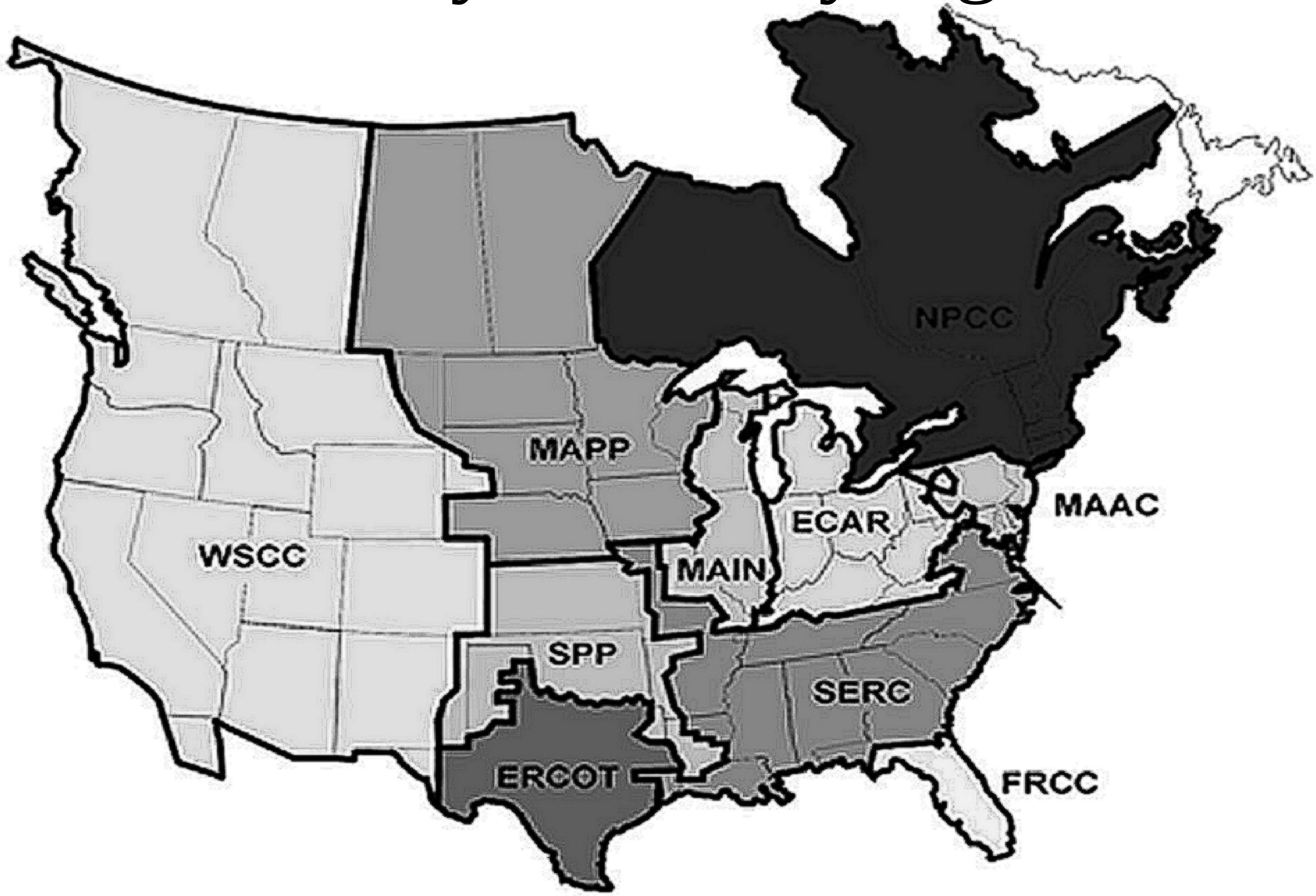


Source: U.S. Energy Information Administration, U.S. DOE, *Annual Energy Review 1999*.

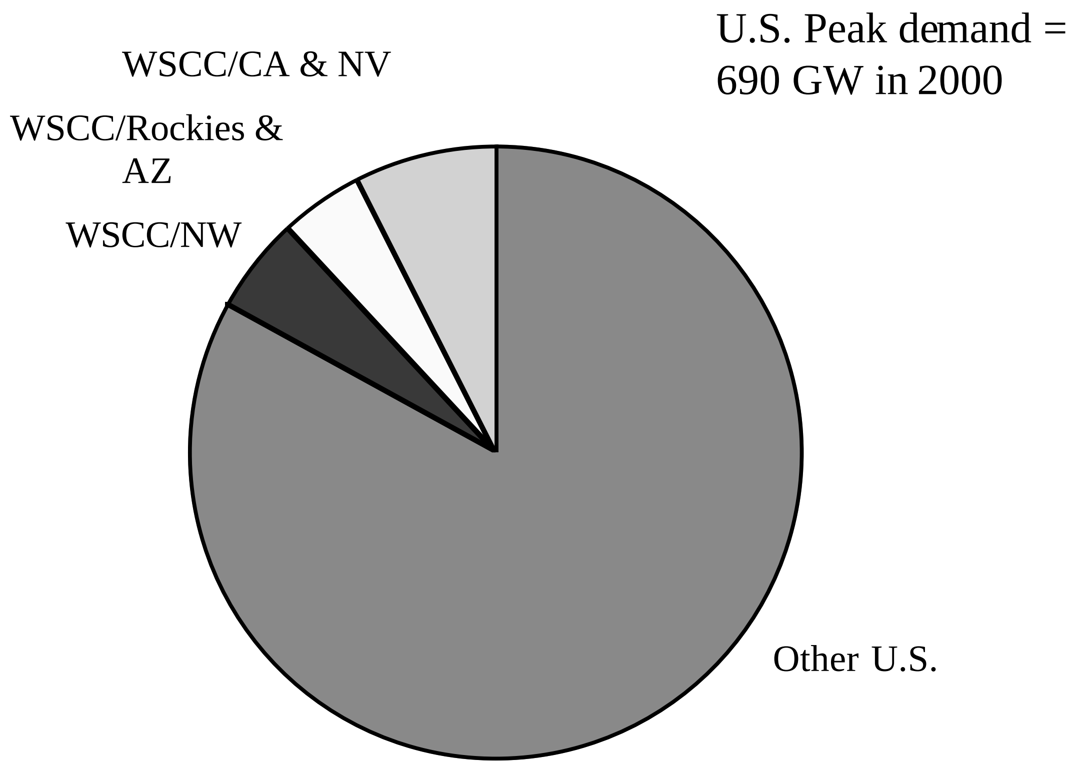
Summary of the U.S. electricity system: An exercise

- Group exercise #4: How big a pile of coal (in cubic meters) is burned by a typical 1000 MW baseload power plant in one year? (Hint: Don't forget the capacity factor)

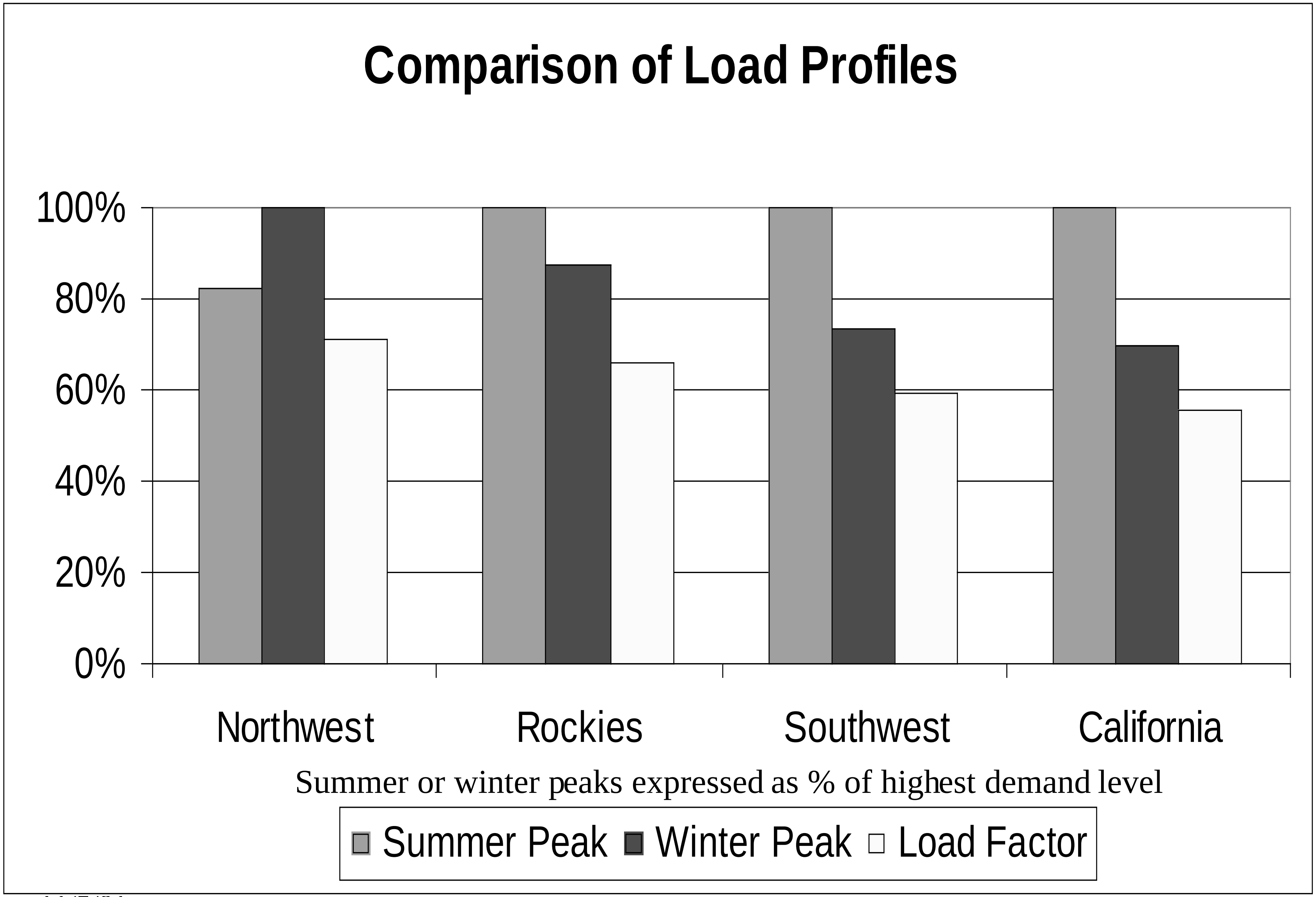
Electricity reliability regions



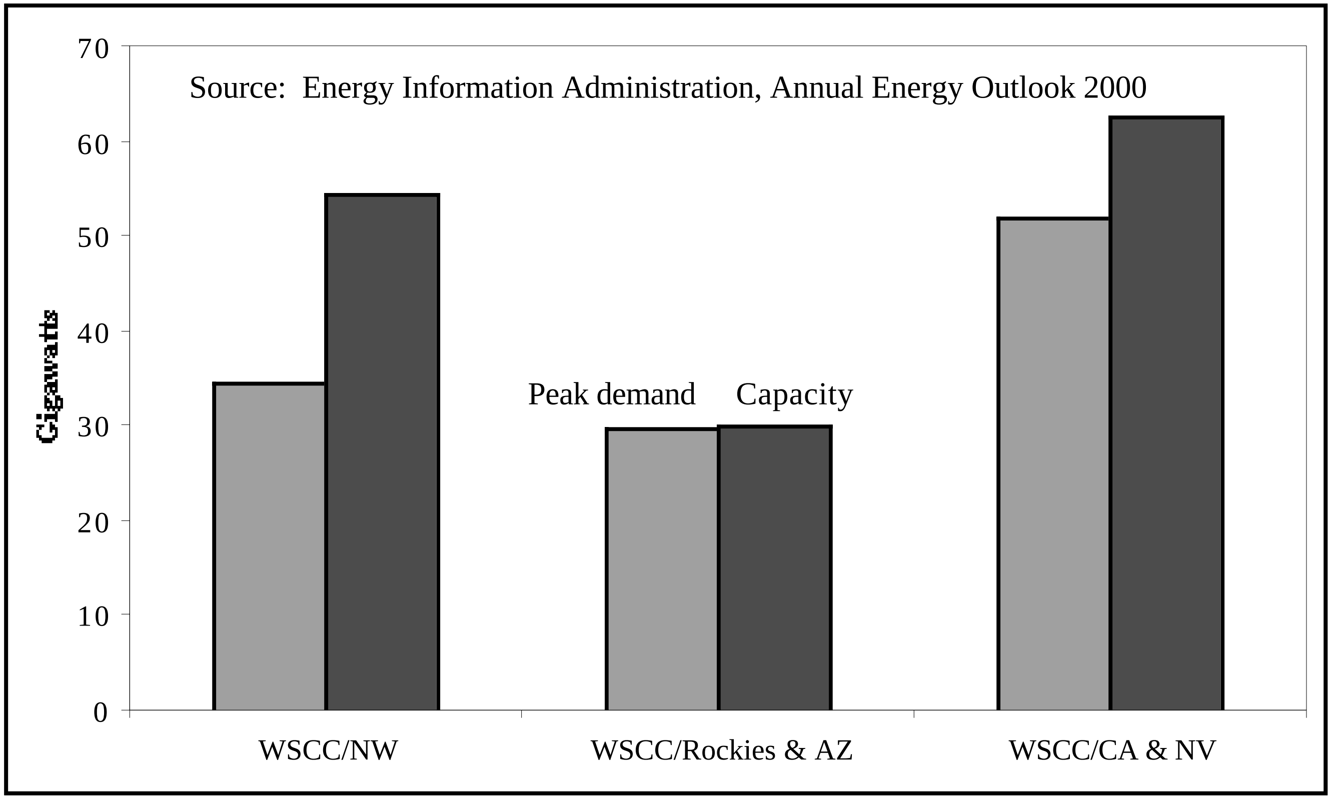
Summary of the U.S. electricity system: Peak demand



Source: U.S. EIA, AEO 2000


Comparison of Load Profiles
100%
80%
60%
40%
20%
0%
Northwest
Rockies
Southwest
California
Summer or winter peaks expressed as % of highest demand level
Summer Peak
Winter Peak
Load Factor

Summary of U.S. electricity system: WSCC demand and capacity



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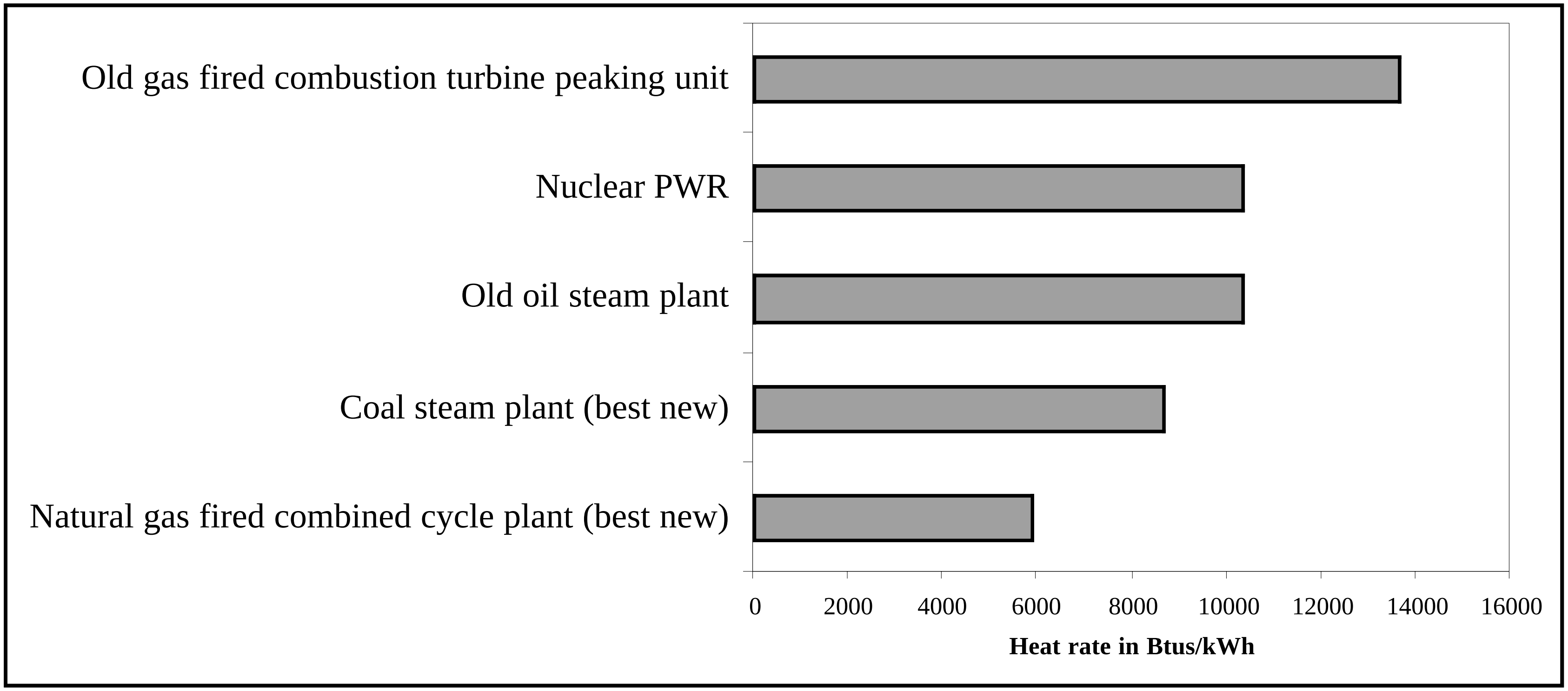
Summary of the U.S. electricity system: Power plant heat rates

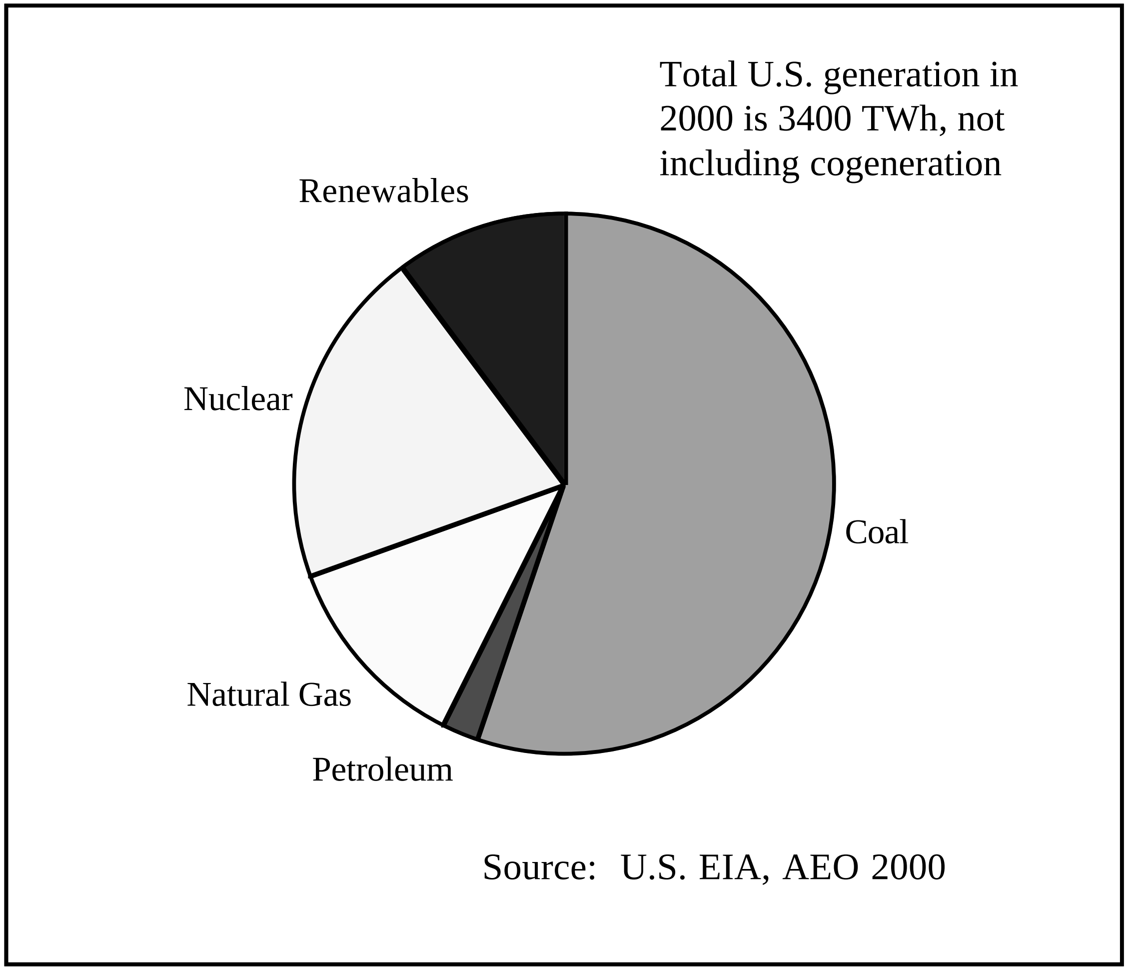
- Heat rates measured efficiency of power plants, and in the U.S. are often expressed in Btus/kWh
- I also express heat rates as a unitless ratio of energy in/energy out (multiply by 3412 to get the more familiar HR in Btus/kWh)
- Watch out for LHV vs. HHV!

Summary of U.S. electricity: Typical power plant heat rates

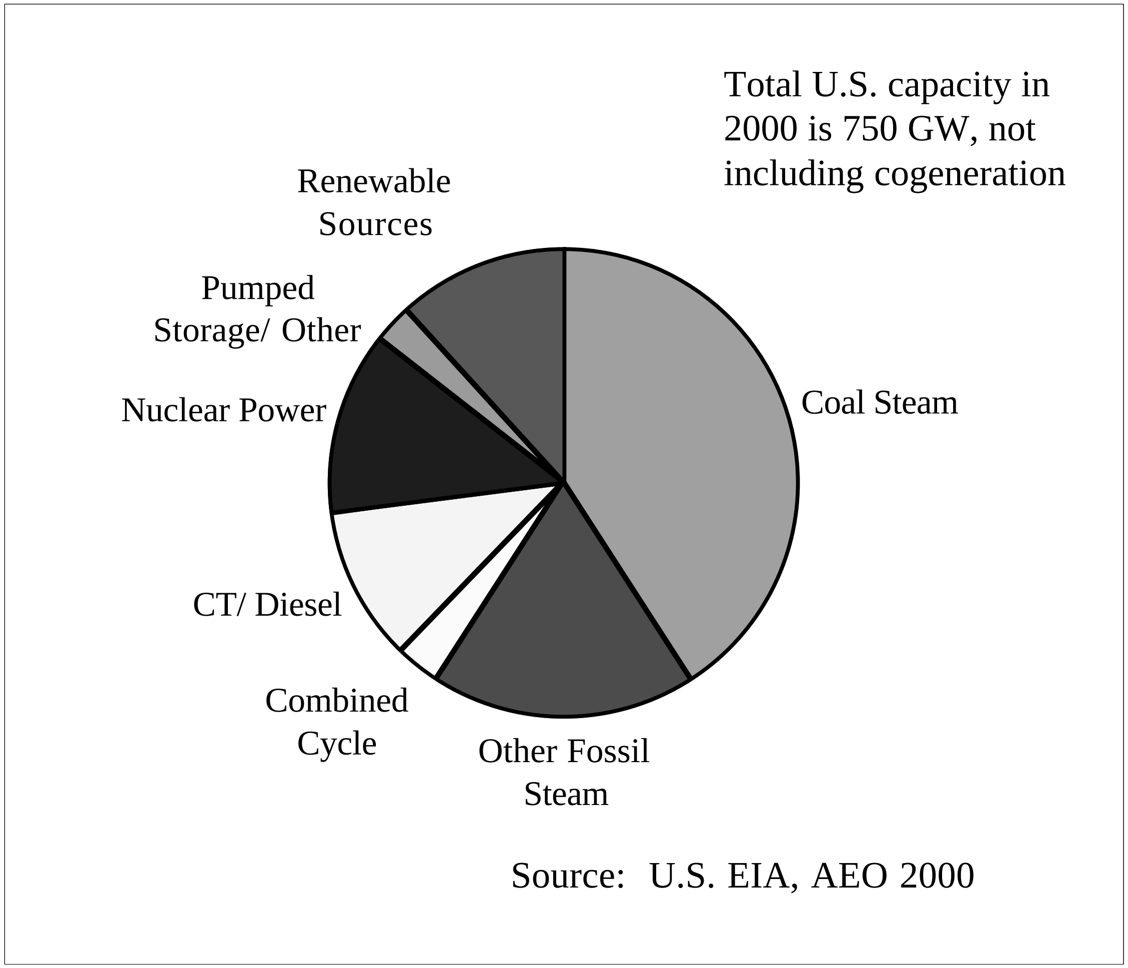


Heat rates for fuels measured using lower heating value.

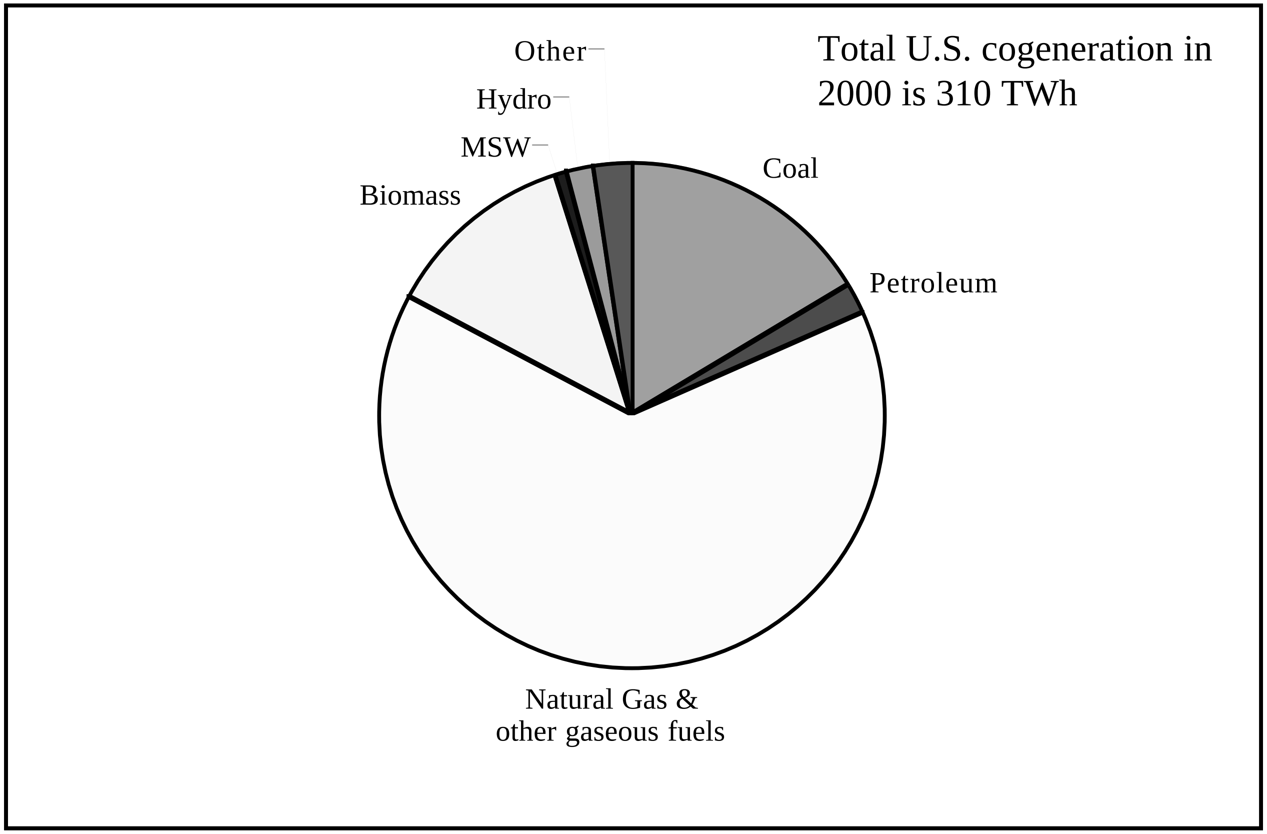
Summary of U.S. electricity: U.S. electric generation--2000



Summary of U.S. electricity: U.S. electric capacity--2000

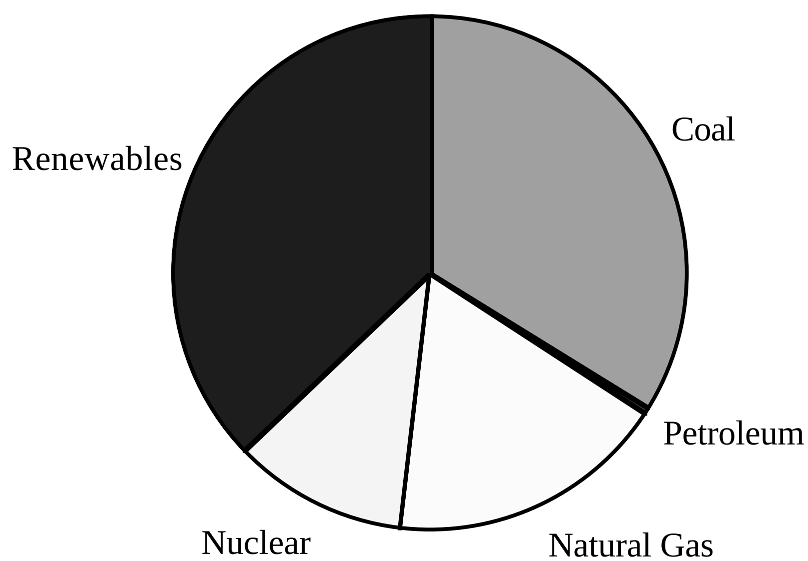


Summary of U.S. electricity: U.S. cogeneration--2000



Summary of U.S. electricity: WSCC electric generation--2000

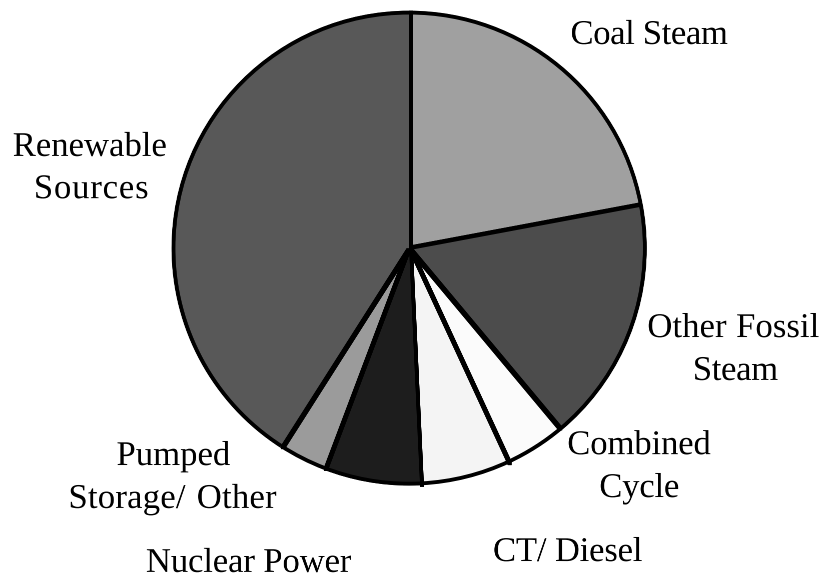
Total WSCC generation in 2000 is 620 TWh, not including cogeneration



Source: U.S. EIA, AEO 2000

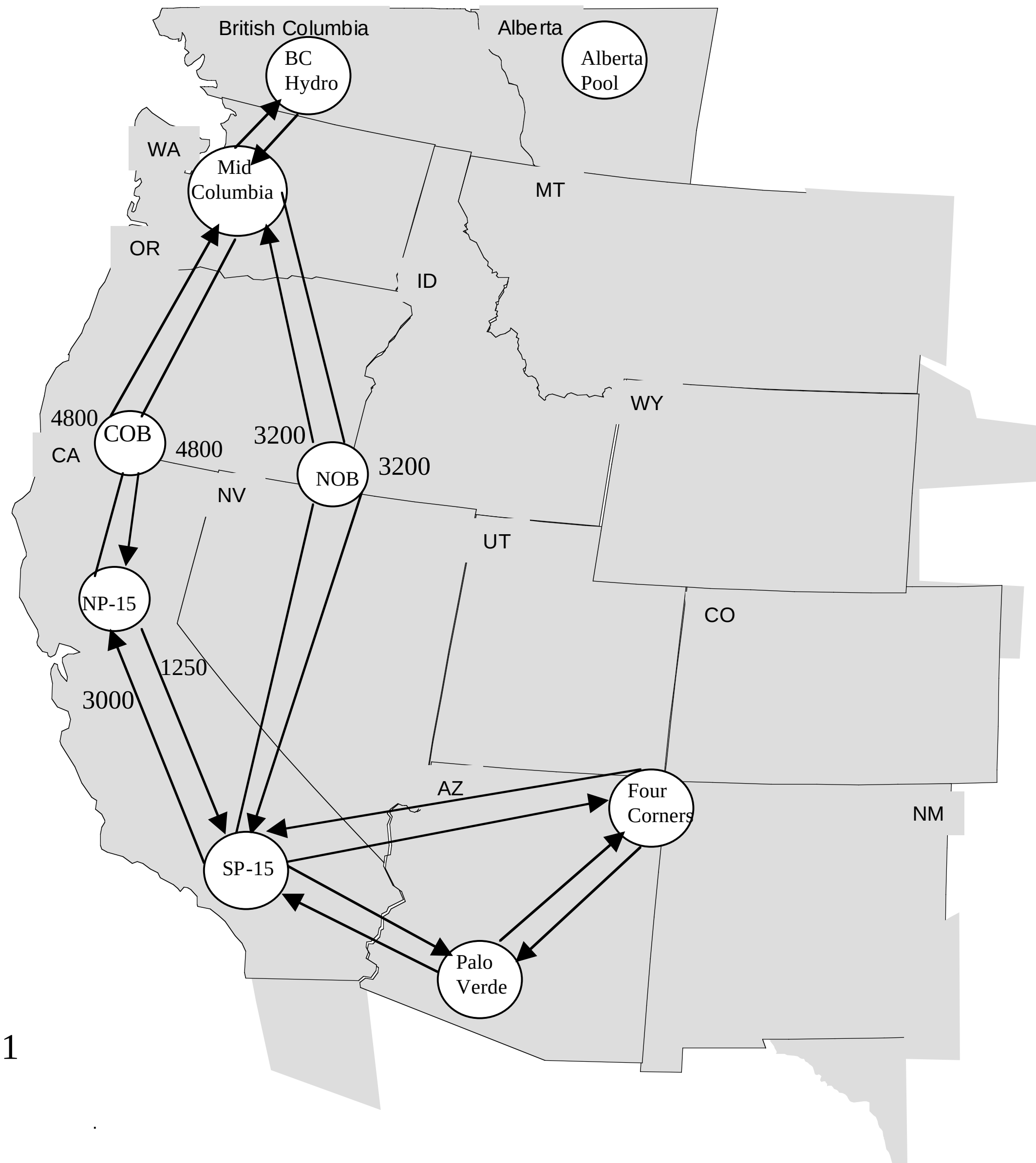
Summary of U.S. electricity: WSCC electric capacity--2000

Total WSCC capacity in 2000 is 140 GW, not including cogeneration

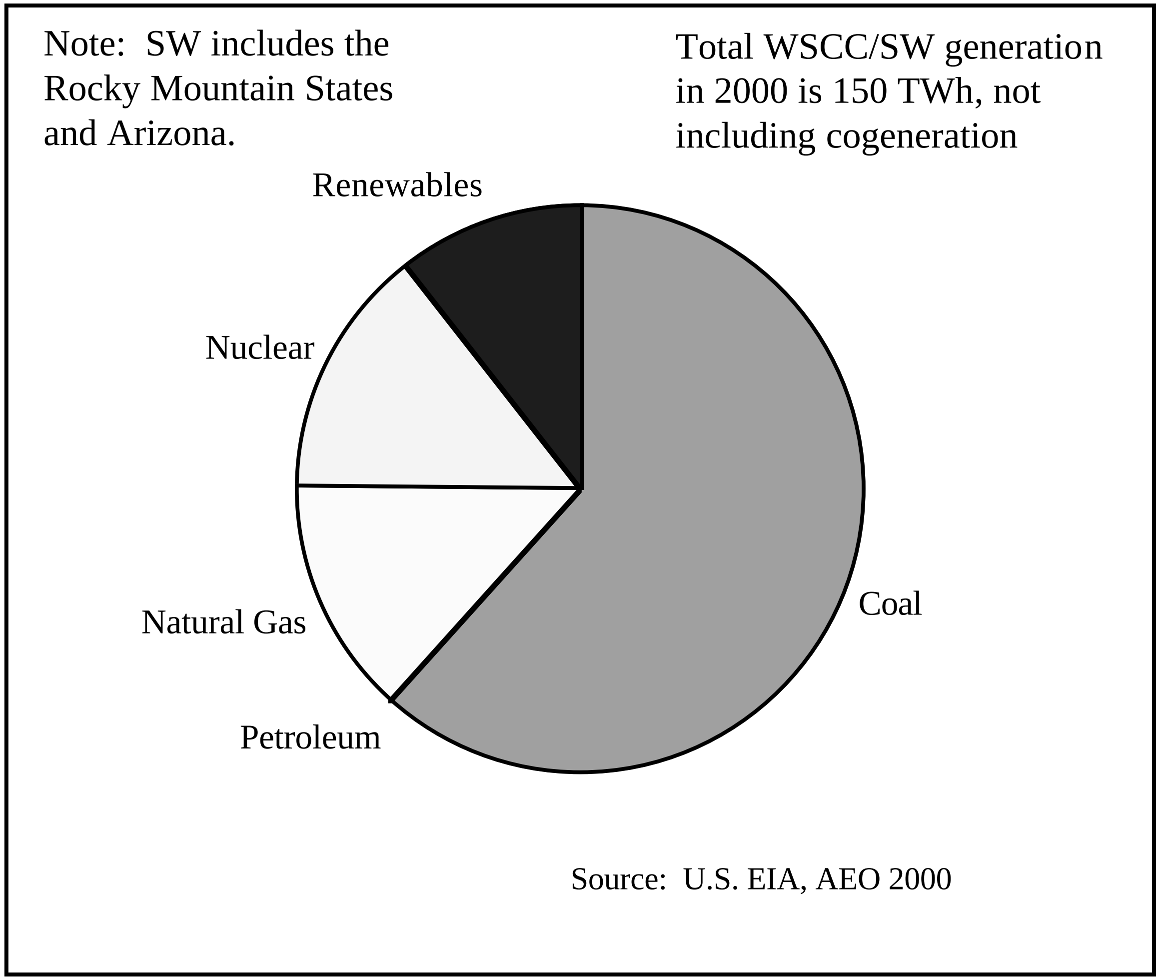


Source: U.S. EIA, AEO 2000

Major WSCC Trading Hubs and Transmission Lines



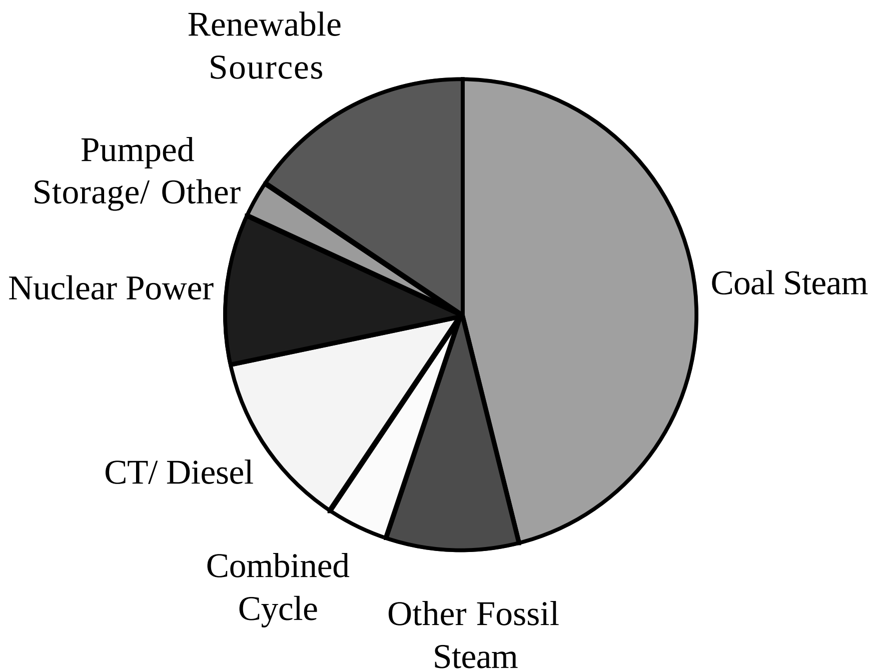
Summary of U.S. electricity: WSCC /SW generation--2000



Summary of U.S. electricity: WSCC/SW capacity--2000

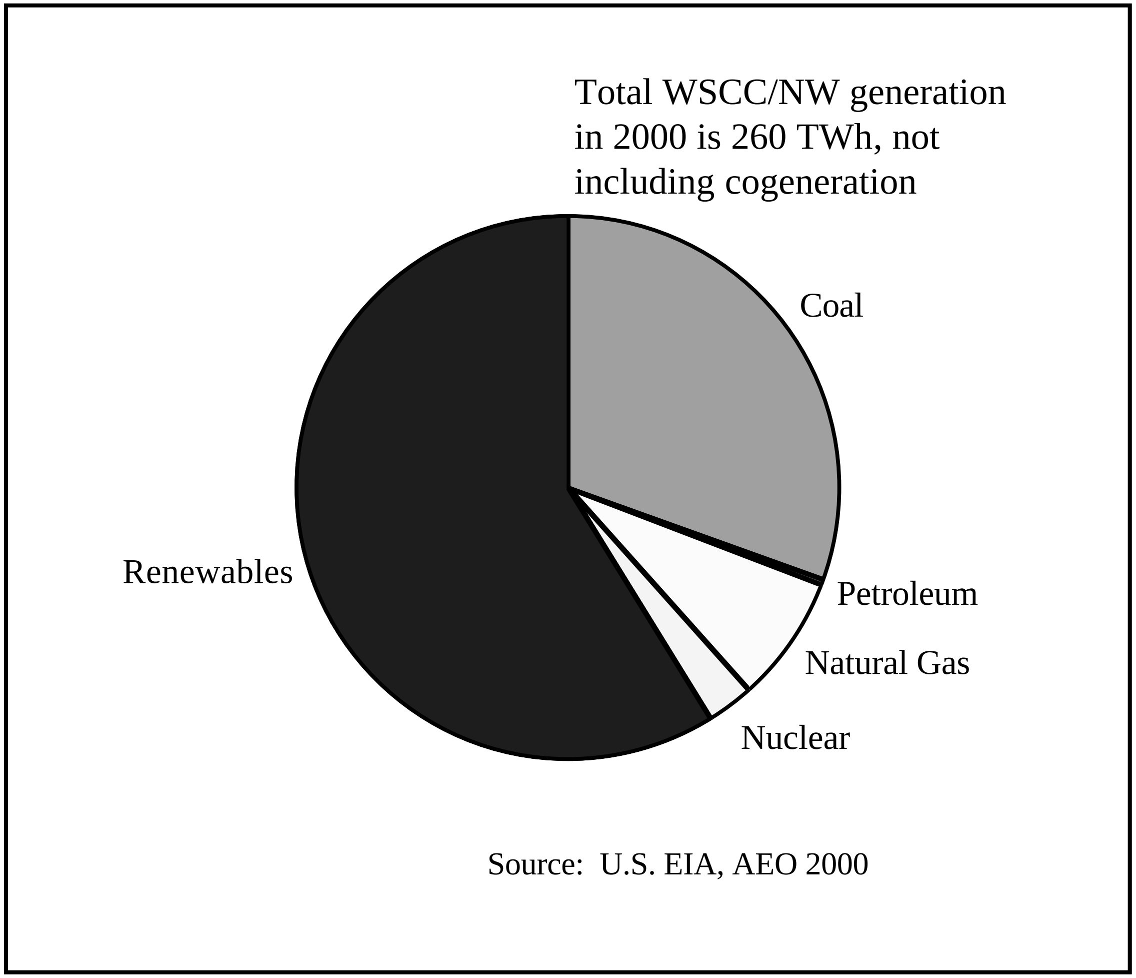
Note: SW includes the Rocky Mountain States and Arizona.

Total WSCC/SW capacity in 2000 is 30 GW, not including cogeneration



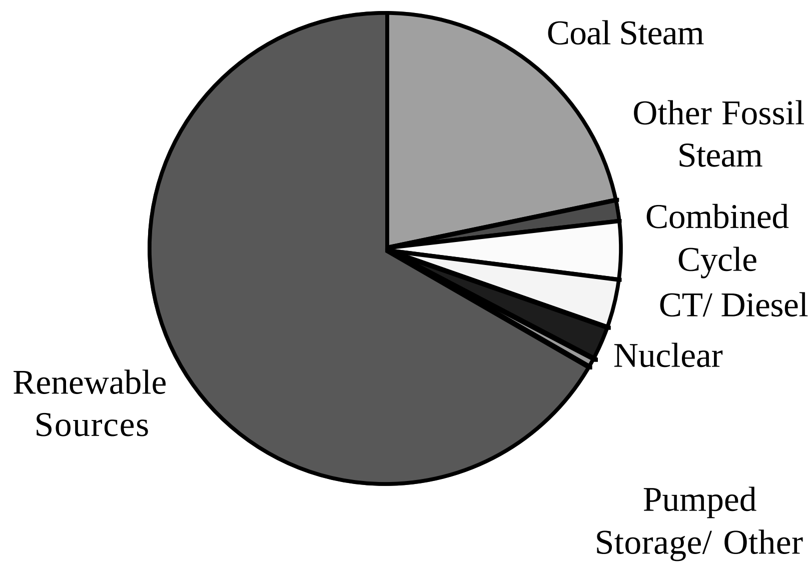
Source: U.S. EIA, AEO 2000

Summary of U.S. electricity: WSCC/NW generation--2000



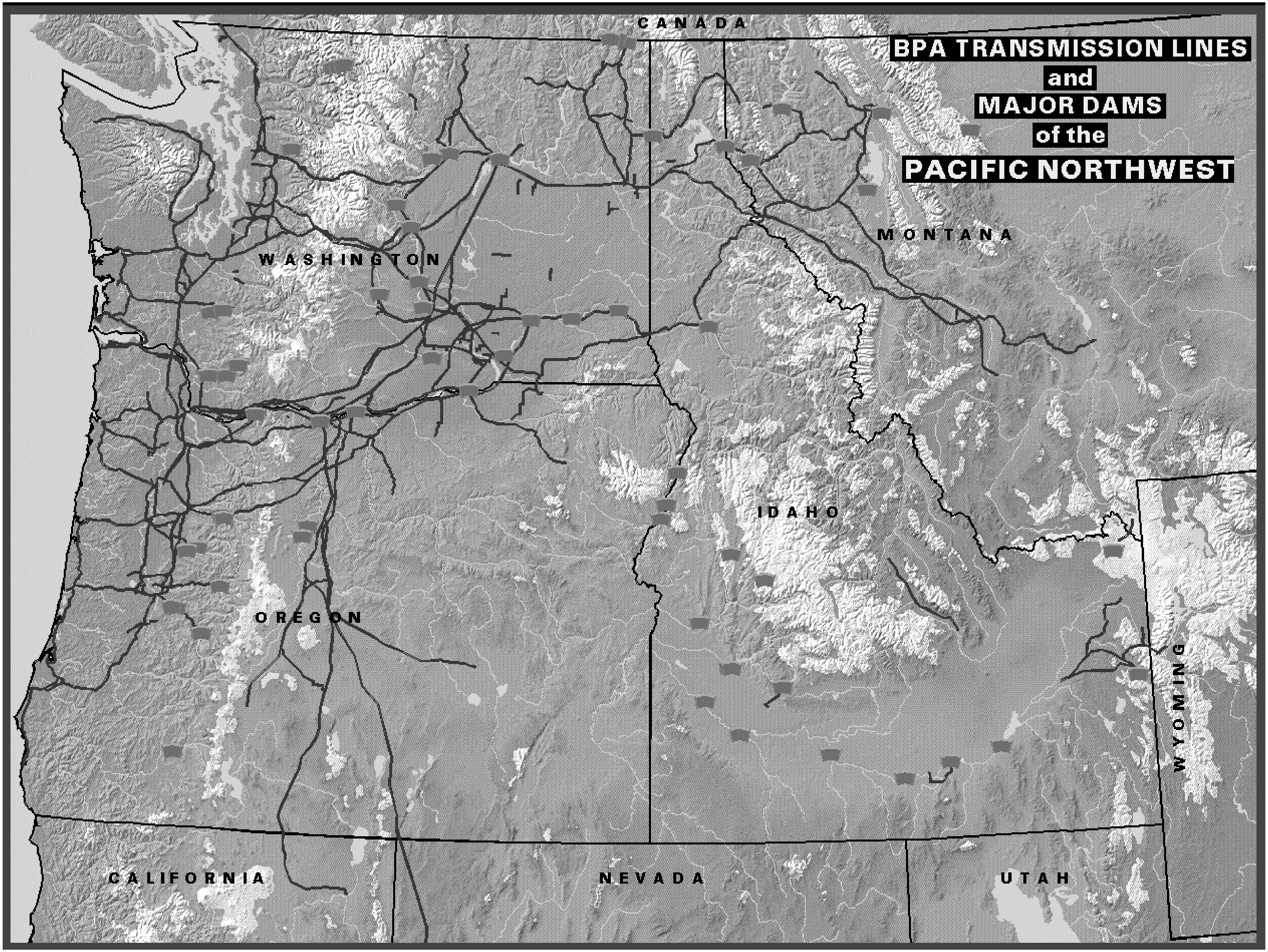
Summary of U.S. electricity: WSCC/NW capacity--2000

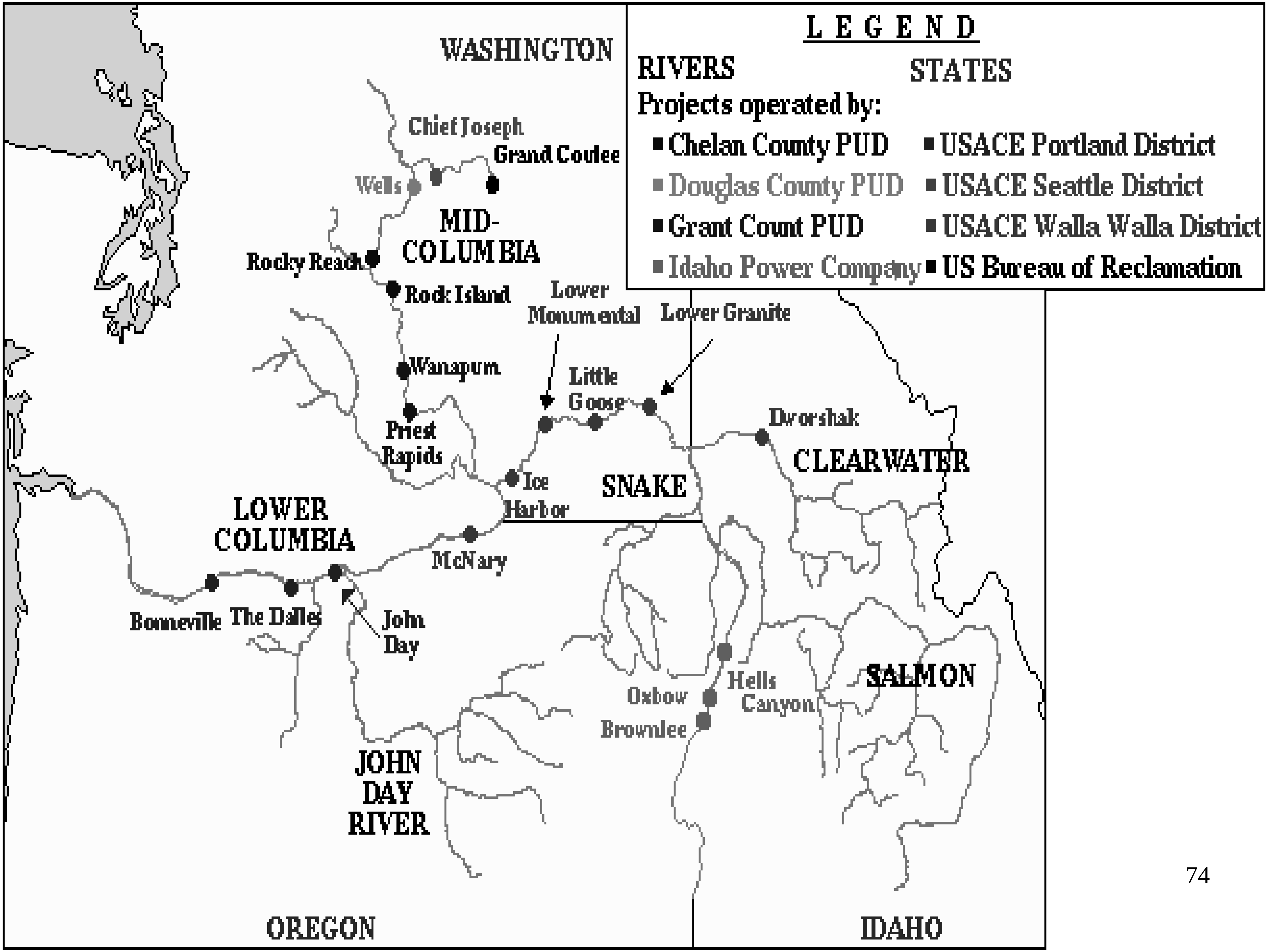
Total WSCC/NW capacity in 2000 is 53 GW, not including cogeneration



Source: U.S. EIA, AEO 2000

Columbia Basin Map


BPA TRANSMISSION LINES
and
MAJOR DAMS
of the
PACIFIC NORTHWEST
CANADA
WASHINGTON
MONTANA
OREGON
IDAHO
WYOMING
CALIFORNIA
NEVADA
UTAH

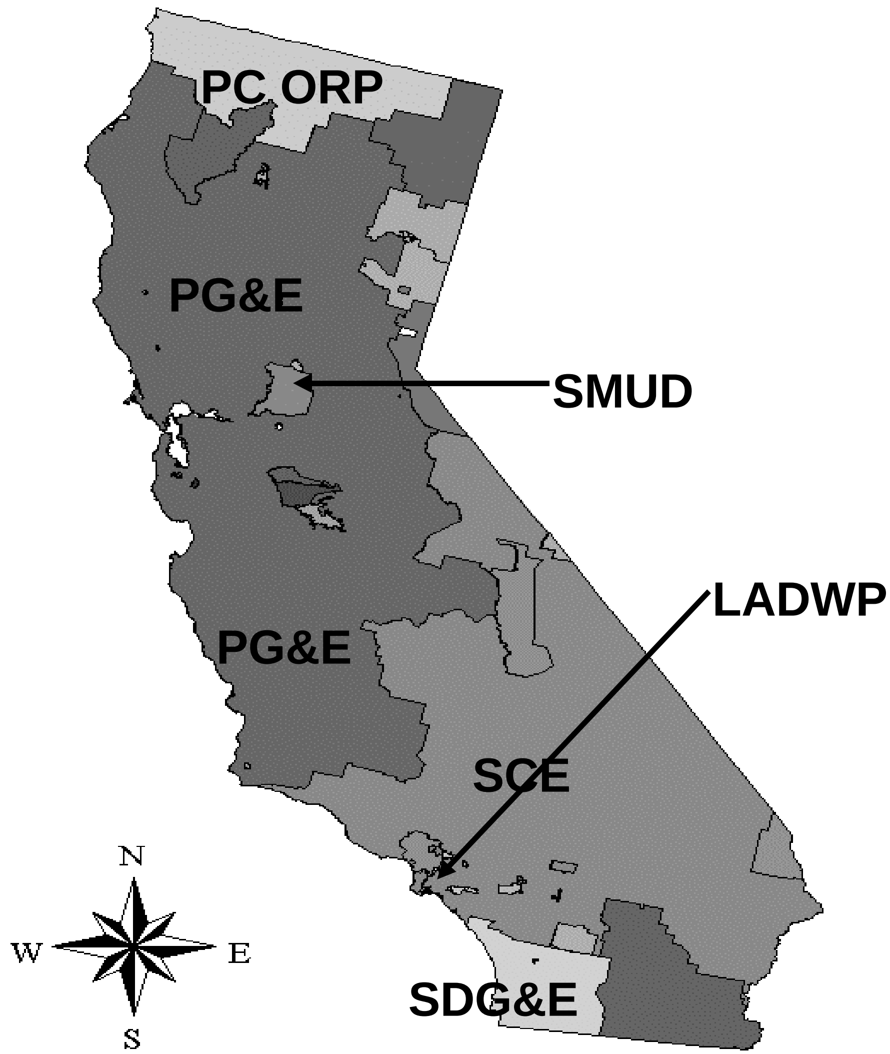


L E G E N D
RIVERS
STATES
Projects operated by:
Chelan County PUD
Douglas County PUD
Grant Count PUD
Idaho Power Company
USACE Portland District
USACE Seattle District
USACE Walla Walla District
US Bureau of Reclamation
WASHINGTON
Chief Joseph
Grand Coulee
Wells
MID-COLUMBIA
Rocky Reach
Rock Island
Wanapum
Priest Rapids
Lower Monumental
Lower Granite
Little Goose
Ice Harbor
SNAKE
Dworshak
CLEARWATER
LOWER COLUMBIA
McNary
Bonneville
The Dalles
John Day
Oxbow
Brownlee
Hells Canyon
SALMON
JOHN DAY RIVER
OREGON
IDAHO

BOE calculations: One more exercise

- Group Exercise # 5: How many acre-feet does a typical U.S. household use per year to take showers? How many gallons and acre-feet is that for the U.S. as a whole?

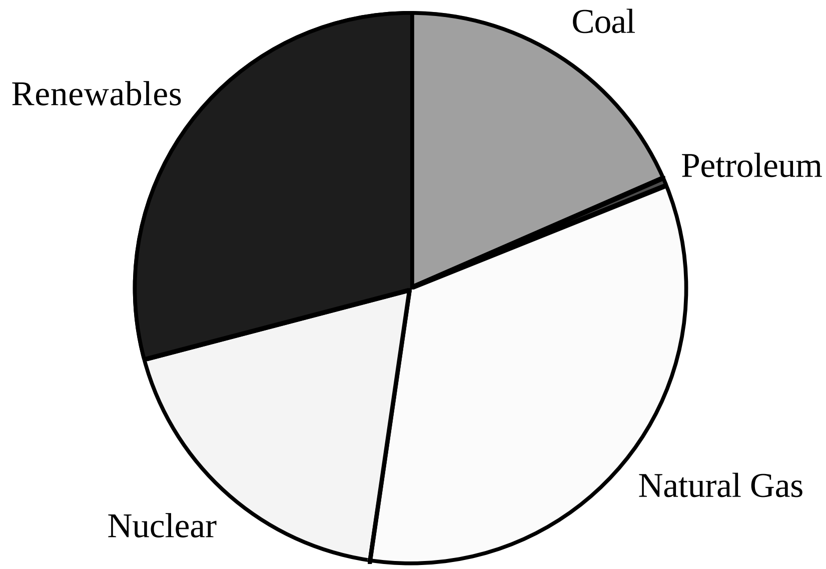
Disco & Utility Service Territories



source: California Energy Commission

Summary of U.S. electricity: WSCC/CA&NV generation--2000

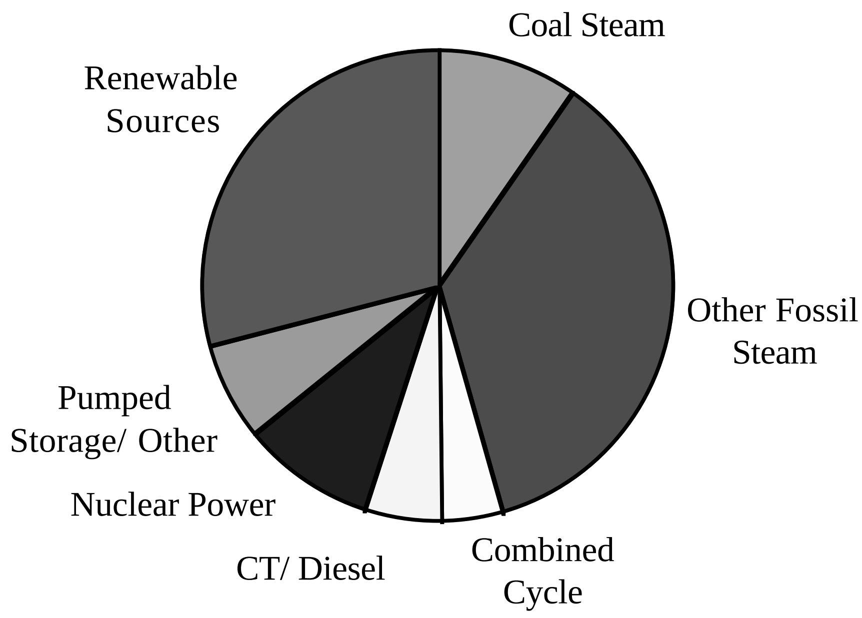
Total WSCC/CA&NV generation in 2000 is 210 TWh, not including cogeneration



Source: U.S. EIA, AEO 2000

Summary of U.S. electricity: WSCC/CA&NV capacity--2000

Total WSCC/CA&NV capacity in 2000 is 56 GW, not including cogeneration

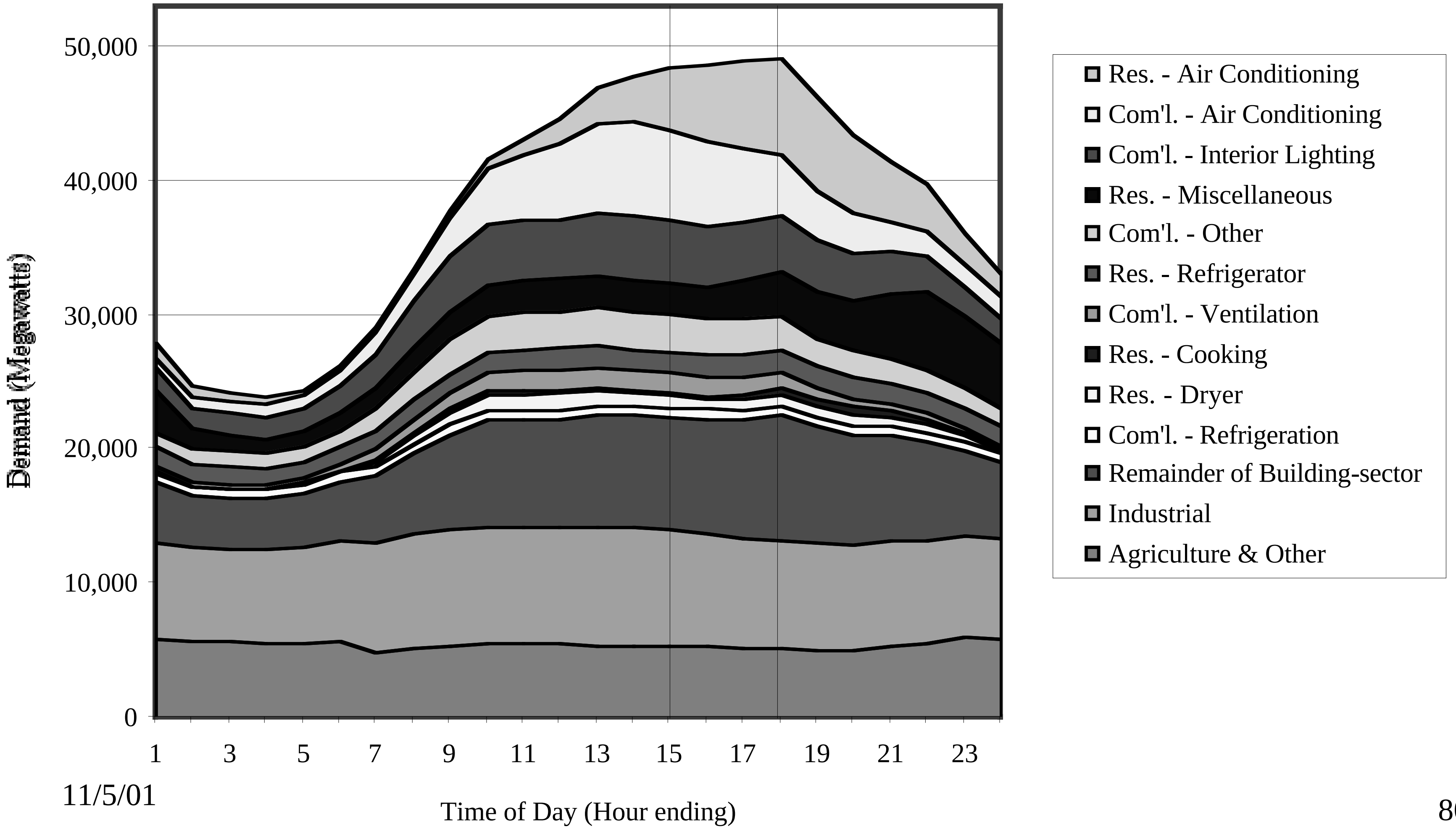


Source: U.S. EIA, AEO 2000

Summary of U.S. electricity: Load characteristics

- What's a load factor? $LF = \dfrac{\text{Average load}}{\text{Peak load}}$
- Typical LFs are 50-60% for utility systems. Industrial LFs are higher, residential LFs are lower. Res. cooling LF can be 5-15%.
- Load factors are a simple way to understand peak demand issues for a particular utility, sector, subsector, or end-use

CA peak day load shape 1999



Source: LBNL analysis of California Energy Commission data

Summary of U.S. electricity: Load characteristics (p. 2)

- Peak vs. avg MW. One average MW for 1 year = 8760 MWh. Over one month = 730 MWh (a MW-month).
- Peak period definition. If peak period is 10 hours per day, a peak MW is equivalent to 10 MWh/day.

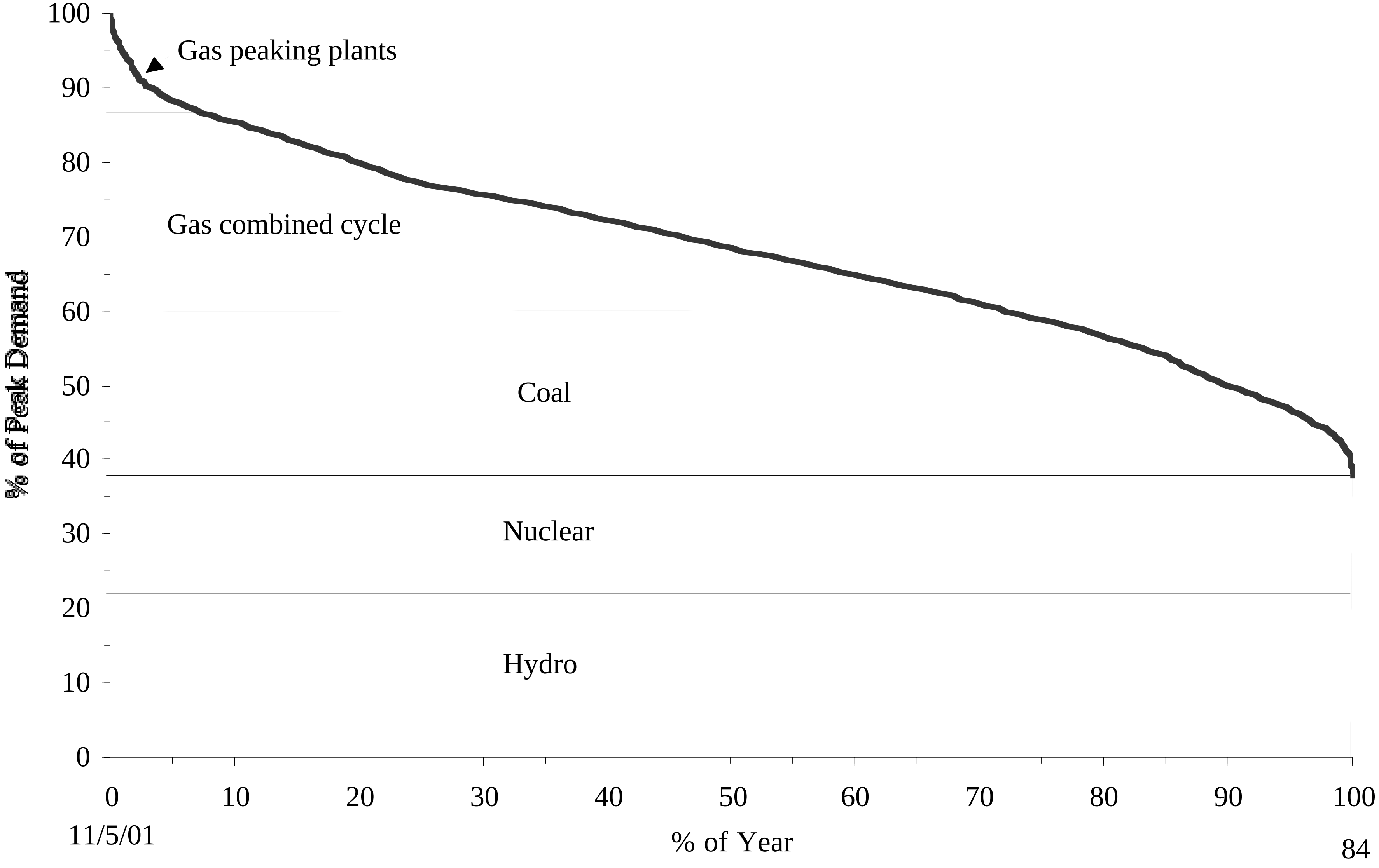
Summary of U.S. electricity: Load characteristics (p. 3)

- Typical definition of peak period in WSCC is from 0700 to 2200, 6 days per week (16 hours per day),
- A peak MW in WSCC is therefore equivalent to 16 MWh per day or about 420 MWh/month.

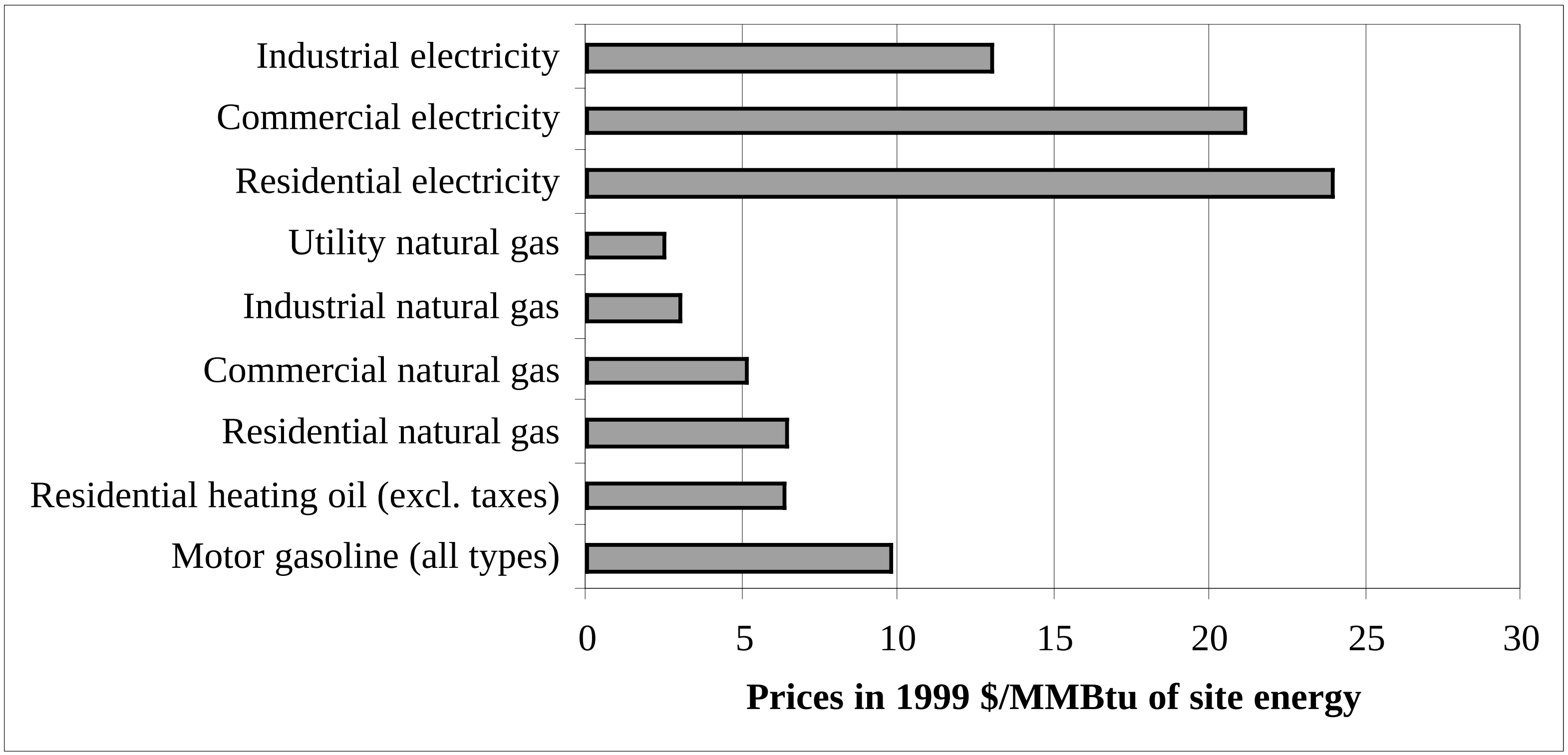
Summary of U.S. electricity: Load duration curves (LDCs)

- Rank order hourly loads starting from the highest to the lowest, assuming independence.
- Stack supply resources up to fill the area under the curve, starting with the lowest marginal cost resources first.
- LDCs were originally developed for computational convenience, but they are still useful conceptual constructs.

Illustrative load duration curve



Summary of U.S. electricity: Prices



Summary of U.S. electricity: Levelized costs of generation

- Need to calculate busbar costs for rough estimates.
- Annualize capital costs (like a mortgage)
- Add in fuel, O&M, and emissions trading costs
- Don’t forget T&D losses to get to delivered costs at the meter.

Summary of U.S. electricity: Calculating levelized cost

Levelized Cost =

$$\left(\frac{\text{Fuel cost/yr} + \text{Capital Cost } x \dfrac{r}{(1-(1+r)^{-n})} + (\text{O \& M/yr})}{\text{Annual Energy Production}} \right) \text{x } 1.06$$

CRF (capital recovery factor) also = $\dfrac{r(1+r)^n}{(1+r)^n - 1}$

n = lifetime, r = interest rate

Summary of U.S. electricity: Calculating levelized cost (p.2)

- Fuel cost

$$\frac{\$5}{MMBtu} \text{ x } \frac{MMBtu}{1{,}000{,}000\,Btu} \text{ x } \frac{6000\ Btu}{kWh} \text{ x } 1.06 \qquad =\$0.032/\text{kWh}$$

- Capital cost of \$500/kW, using CRF = 0.1, fixed O&M of \$30/kW/year, 91.3% CF

$$\left(\frac{\$500}{\text{kW}} \text{ x } 0.1 + \frac{\$30/\text{kW}}{\text{year}}\right) \text{ x } \frac{1 \text{ kW - year}}{8000 \text{ kWh}} \text{ x } 1.06 = \$0.01/\text{kWh}$$

- Add variable O&M of \$0.005/kWh
- Then add cost of NO_x permits.

Summary of U.S. electricity: Calculating levelized cost (p.3)

- Emissions permit cost =

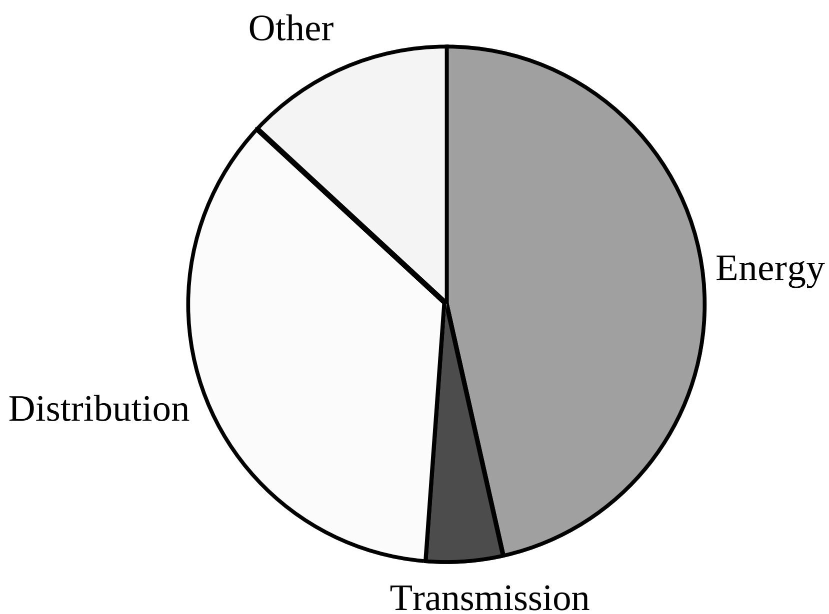
$$\frac{0.035 \text{ lbs } NO_x}{\text{MMBtu}} \text{ x } \frac{1 \text{ MMBtu}}{10^6 \text{ Btu}} \text{ x } \frac{6000 \text{ Btu}}{\text{kWh}} \text{ x } \frac{\$14 \text{ (in 2000 \$)}}{1 \text{ lb } NO_x} \text{ x } 1.06 \qquad = \$0.003/\text{kWh}$$

- Total delivered cost of power =

$$\$0.032 + 0.01 + 0.005 + 0.003 = \$0.05/\text{kWh}$$

Summary of U.S. electricity: Costs of power to CA residences

Total electricity price for CA residences is about $0.12/kWh in 2000



Distribution from Jon Koomey's utility bill, January 2001

Summary of U.S. electricity: Introduction to forecasting

- Forecasts are used
  - For planning (either institutional or personal)
  - For advocacy (to raise awareness of an issue)
  - For research (to explore the future)
- All forecasts are wrong in some respect, but they are usually still valuable
  - Systemize an investigation into future choices.

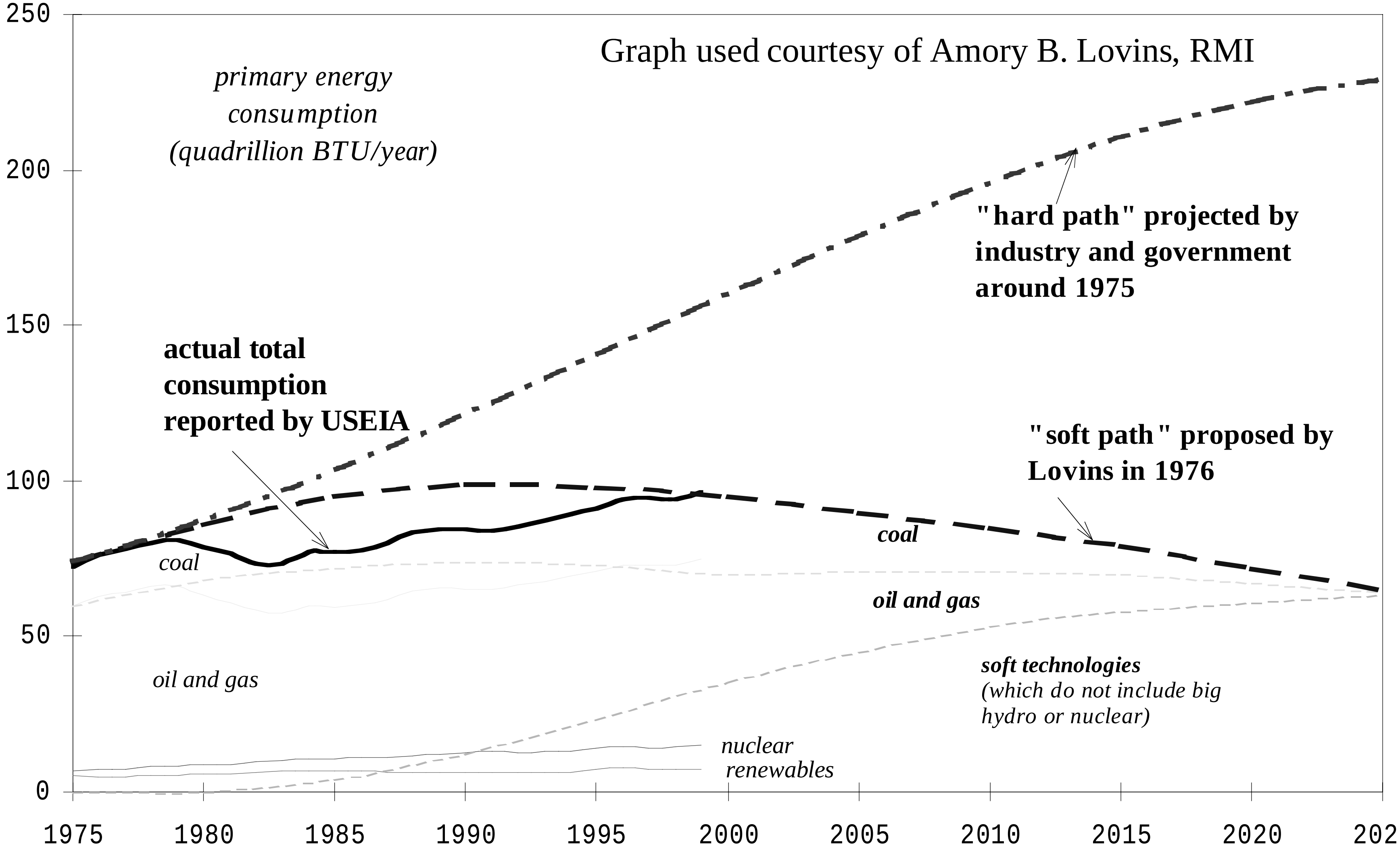
Summary of U.S. electricity: Background on forecasting

- The most basic forecasts are econometric or trend based, using simple extrapolation or regressions on historical data.
- These techniques are notoriously inaccurate for energy demand forecasting, except for short term projections.
- Inaccuracy of econometric forecasts in the 1970s and early 1980s led to widespread use of the "end-use" approach in the U.S. by the late 1980s.

Summary of U.S. electricity: Forecasts vs. scenarios

- A forecast is a prediction of how the future WILL unfold.
- A scenario is a story of how the future MIGHT unfold if certain events come to pass (there is always more than one scenario) .
- Scenarios are used for making decisions in the face of uncertainty (example: Royal Dutch Shell in the early 1970s).

US Primary Energy Consumption Is Now Within 2% of the 1976 “Soft Energy Path”



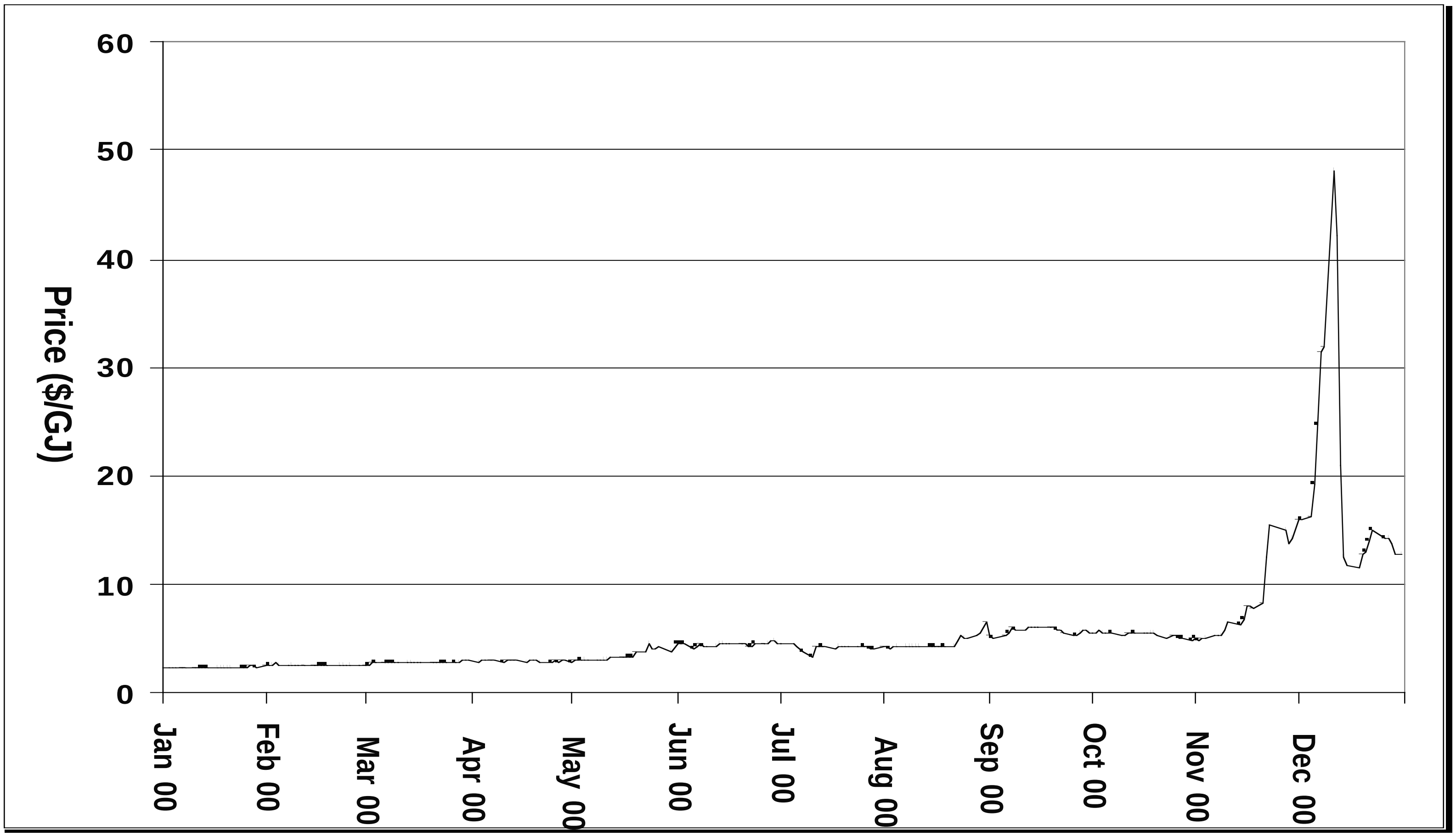
Summary of U.S. electricity: More on scenarios

- Tell stories using scenarios to help develop your intuition about the key driving forces affecting the future.
- Develop strategies that are robust in the face of inevitably imperfect forecasts (e.g., build-to-order manufacturing).

The Golden Rules of Scenario Analysis

- Models can be useful, but the focus should be on data development and scenario creation, NOT modeling. Models always lag the state of knowledge about new energy resources.
- Watch out for the unexpected!

Gas Spot Price at PG&E Citygate for 2000



Summary of U.S. electricity: Exponential growth

- Many phenomena grow exponentially for part of their life cycle.
  - Characterized by an annual growth rate, say 2% per year
- Exponential growth can be powerful over the long term (retirement planning--20 year old vs 30 year old).
- Review growth rate calcs

Summary of U.S. electricity: Exponential growth (p. 2)

- A key trick of the trade -- “the rule of 70”.
  - For any annual growth rate, (e.g., 2% /yr), you can calculate the time for something growing at that rate to double, by dividing 70 by the growth rate (doubling time = 35 yrs)
- Can use doubling times to do quick calculations when the data don’t warrant more detailed work or if you don’t have time

Summary of U.S. electricity: Forecasting exercise

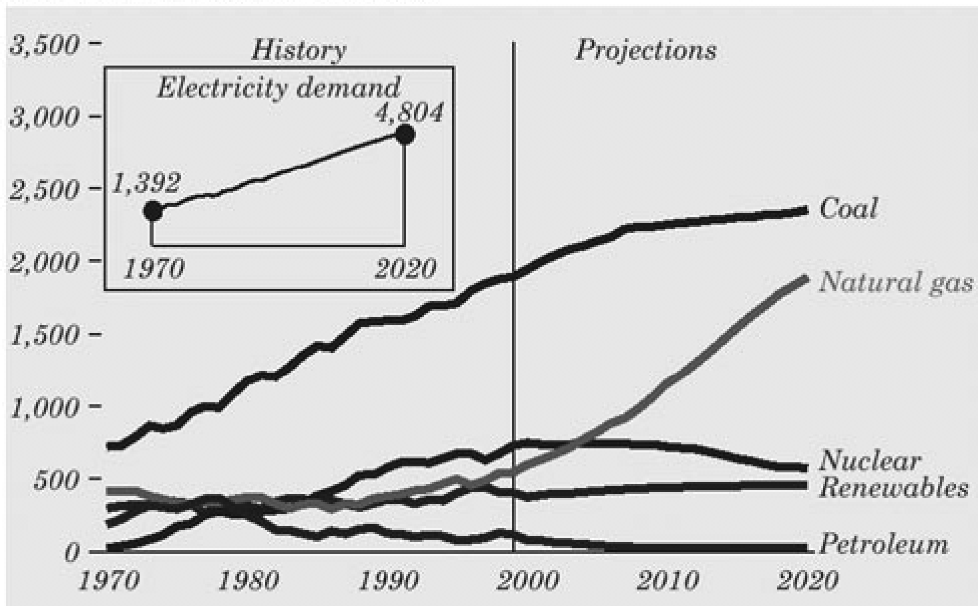
- Group Exercise # 6: Some have claimed that electricity used by office equipment is about 13% of all electricity use now, and that it will grow to half of all electricity use in 20 years. The same folks are claiming that all electricity use will grow 3.5% per year for 20 years, and that most of that growth will be due to increased electricity used by office equipment. Are these claims internally consistent? (note, these claims are not correct, but that's another story). Total electricity use in the U.S. in 1999 was about 3300 billion kWh.

Summary of U.S. electricity: Another exercise (for after class)

- Find a forecast on a topic you care about (doesn’t have to be electricity), and learn how it was created. Talk to the author and read any supporting documentation. Do you still find it plausible?

Summary of U.S. electricity: Forecasted electricity generation

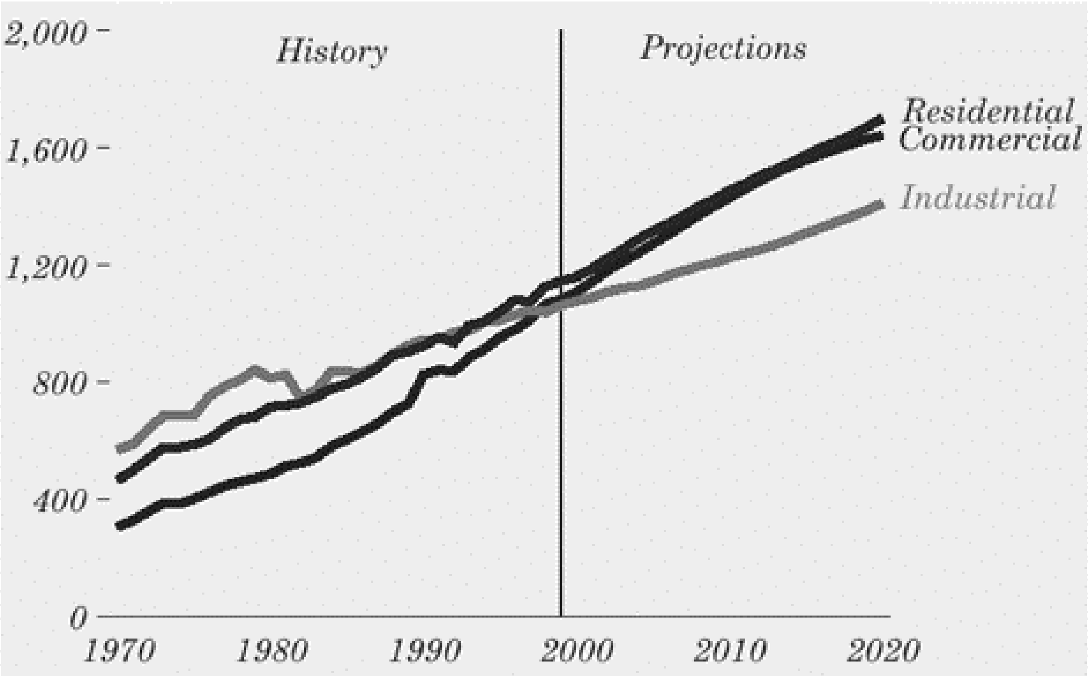
Figure 4. Electricity generation by fuel, 1970-2020 (billion kilowatthours)



History: Energy Information Administration (EIA), Form EIA-860B, "Annual Electric Generator Report - Nonutility;" EIA, *Annual Energy Review 1999*, DOE/EIA-0384(99) (Washington, DC, July 2000); and Edison Electric Institute. **Projections:** Table A8.

Summary of U.S. electricity: Forecasted electricity sales

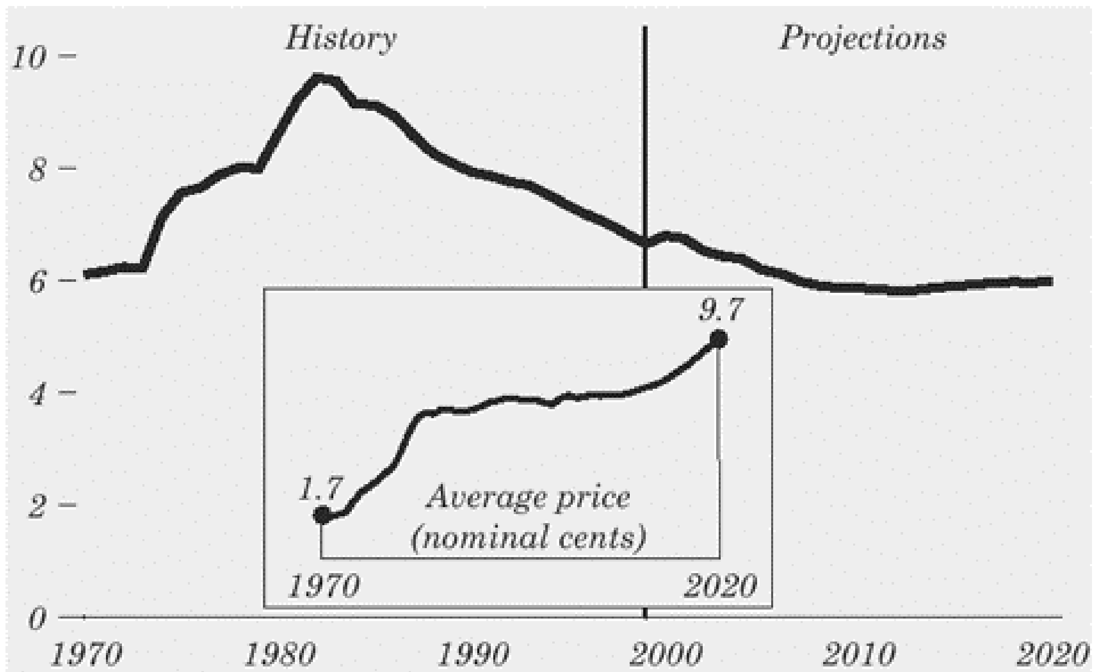
Figure 71. Annual electricity sales by sector, 1970-2020 (billion kilowatthours)



Energy Information Administration, *Annual Energy Review 1999*, DOE/EIA-0384(99) (Washington, DC, July 2000). **Projections:** Table A8.

Summary of U.S. electricity: Forecasted electricity price

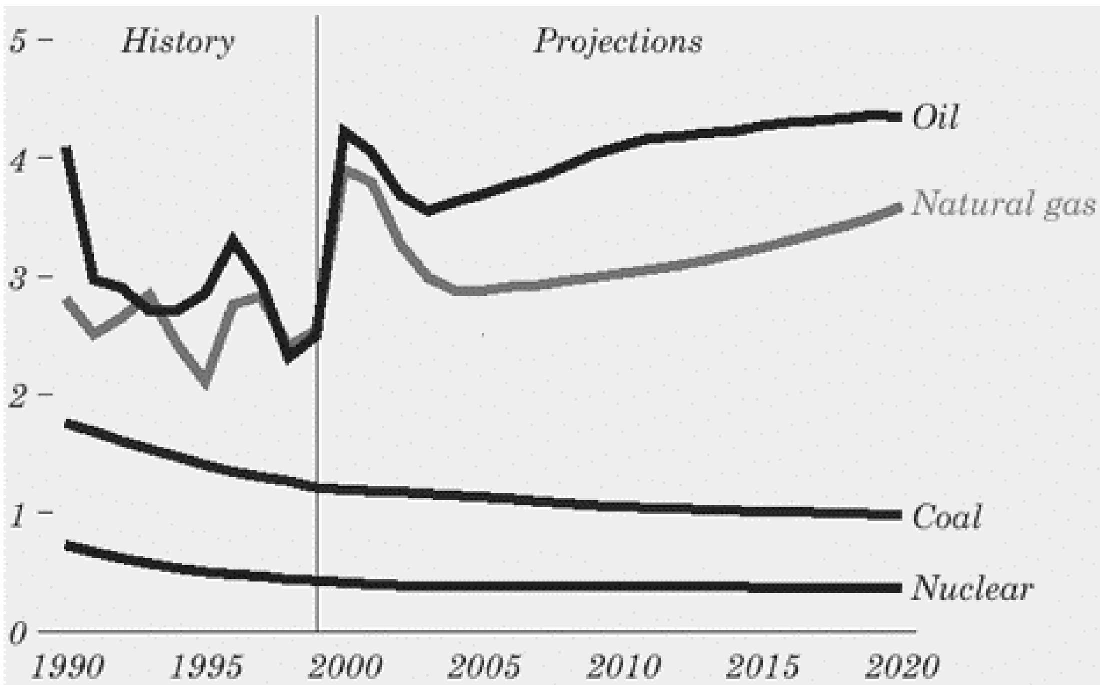
Figure 75. Average U.S. retail electricity prices, 1970-2020 (1999 cents per kilowatthour)



Energy Information Administration, *Annual Energy Review 1999*, DOE/EIA-0384(99) (Washington, DC, July 2000). **Projections:** Table A8.

Summary of U.S. electricity: Forecasted generator fuel costs

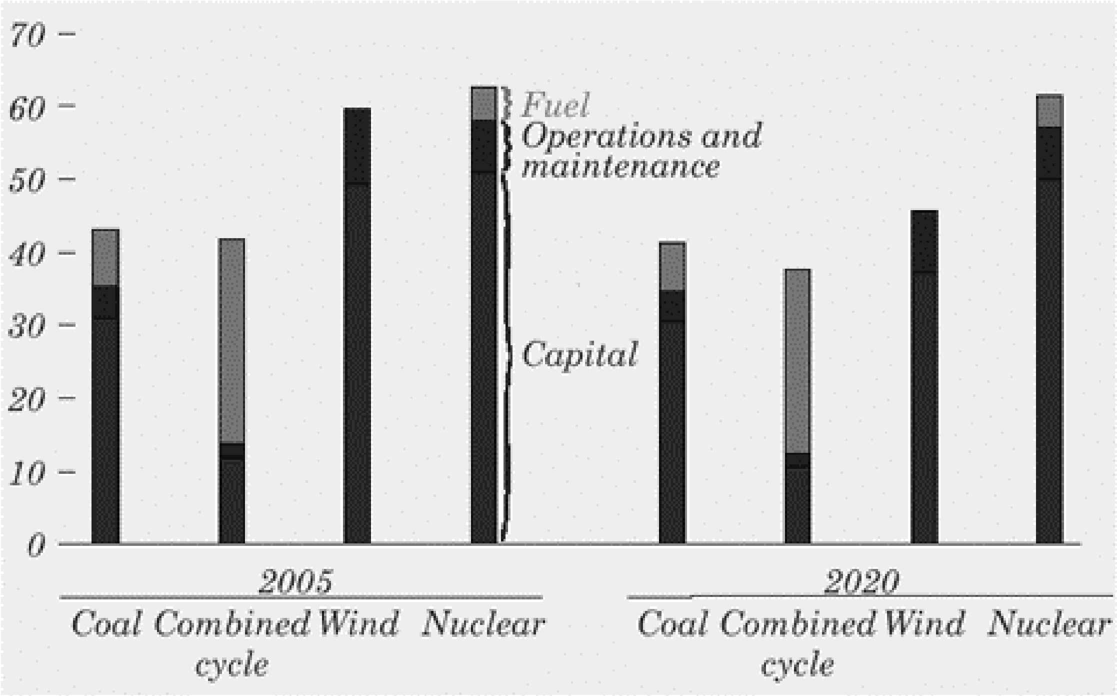
Figure 74. Fuel prices to electricity generators, 1990-2020 (1999 dollars per million Btu)



Energy Information Administration, *Annual Energy Review 1999*, DOE/EIA-0384(99) (Washington, DC, July 2000). **Projections:** Table A3.

Summary of U.S. electricity: Forecasted generation costs

Figure 76. Projected electricity generation costs, 2005 and 2020 (1999 mills per kilowatthour)



AEO2001 National Energy Modeling System, run AEO2001.D101600A.

Conclusions/wrap up

- Be deliberate, systematic, and methodical in how you use and present information.
- Value your time and that of others—your time is your life, so make it count.
- Questions or comments? Turn in your evaluations to Grace. You can also email me at numbers@numbersintoknowledge.com